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INDUSTRIAL DEVELOPMENT ORGANIZATION

GUIDELINES

FOR PROCESSING ALUMINIUM SEMI-FABRICATED PRODUCTS*

Prepared by

a working team**

of ALUTERV-FKI, Budapest, Hungary

under the leadership of

A. Domony***

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** V. Sapsal, Ph.D. Chem.Eng.; L. Schippert, Ph.D. Met.Eng.; J. Csák, Ph.D. Met.Eng.

*** Chief Editor, Magyar Aluminium, Budapest, Hungary.

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EXPLANATORY NOTES

References to dollars /$/ are to United States dollars unless otherwise stated

The investment costs and suggested capacities in this study are estimated values.

The investment costs are given in dollars of the year 1982-1983

DIN = Deutsche Industrie Normen /Industry Standards of FRG /
VDE = Verein Deutscher Elektrotechniker /Society of German Electrotechn. FRG /

1. INTRODUCTION AND AIM OF THE STUDY

The promotion of establishment or expansion of aluminium industries in developing countries is one of the major preoccupations of UNIDO. This trend is based on the realization that more than 75% of the world's bauxite resources are located in developing countries, i.e. 36% in Africa, 28% in Latin-America and 11% in Asia. This situation is linked with another aspect of developing an aluminium industry: the availability of inexpensive electric energy necessary in running power-intensive smelter operations. At present only 5-10% of the cheap and environment-friendly hydroelectric power potential available in developing countries is tapped for practical ends. This is why at the 1975 Second General Conference of UNIDO in Lima developing countries had been strongly recommended to devote their particular attention to set up basic industries, amongst others that of aluminium, so that by the turn of the century their share of industrial output should account for 25% of the world's total industrial production.

Since then, UNIDO has given substantial support to the realization of this initiative. To begin with, it has strongly boosted the setting-up of raw material-producing industries of their own in developing countries (1), (2). Following this, it launched a campaign of familiarizing developing countries with the inherent advantages of having also an aluminium-processing industry of their own. In support of this, a special case study was prepared under UNIDO'S auspices dealing with the techno-economic feasibility of manufacturing aluminium finished products (3). A further publication has discussed possibilities of setting-up finished product manufacturing facilities in combination with adequate semi-fabricating capacities in a given developing country (4). In October 1983, a conference was organized by the Kuwait Chamber of Commerce and Industry in conjunction with Kuwait Aluminium Co., UNIDO and the Arab Federation for Engineering Industries. The central topic of this venue had been the situation of industry in Arab countries, with special regard to the status and future prospects of aluminium semi-manufacturing in such areas (5). And finally, a survey was prepared on the aluminium semi-fabricating industry of 50 developing countries by Prof. Kumar (6).

Prof. Kumar's study, amongst others, also pointed out that while world trade of aluminium raw materials as a whole had been steadily growing, increasingly large volumes of semi-manufactures had been exported to developed countries, a fact opening up new perspectives for developing countries to improve their balance of payments. In his study considerable space is also devoted to the fact that the installation of aluminium-processing capacities for the manufacture of semi-fabricated and fabricated products is a less capital-intensive proposition than that of raw-material producing projects. The former, moreover, may be run in a techno-economically feasible manner even at small capacities despite the series of more or less labour-intensive operations involved, believed to be of special attraction to developing countries. It is on this understanding that yet another UNIDO study was completed in 1984, wherein the establishment of a complete extrusion plant in developing countries has been amply dealt with, along with all of its techno-economic aspects and advantages (7).

As far as the present study is concerned, its objective is to familiarize the reader with technical trends in establishing a modern aluminium semi-fabricating industry, with special heed to possibilities in developing countries. It tries to suggest optimum solutions depending on the raw material situation, infrastructure, manpower and market position of developing countries. The processing of aluminium is an issue wherein next to aluminium specialists also manufacturers of semi-fabricating and other processing equipment, dealers of semi-manufactures and last but not least the end-user itself have their say. Evidently, partners from such varied fields do call for a common language. The present study is designed to help to meet this particular demand too. Principal operations of semi-manufacture are discussed under seven sub-chapters /3.3-3.9/. Each of them briefly refers to different technical alternatives along with advantages and disadvantages as the case may be, suggesting various ways and means of how a project may best be implemented, and recommending sources from where technical asistance and know-how may be forthcoming.

Of course, the present study may not embrace all technological details of semi-manufacturing in their entity; it is actually designed to

- furnish information and assistance to decision-makers of industrial strategies in developing countries on principal trends and prospects of technical development in this particular sphere of the aluminium industry
- reduce, as far as possible, time and costs involved in the preparatory stages of projects envisaged
- point out interactions with other areas of the aluminium industry both from a domestic point of view and with regard to foreign trade, and
- present an exercise in response to which useful observations and new ideas are always welcome.

2. THE METAL SUPPLY SITUATION

2.1 Present world primary aluminium output and forecasts until the year 2000 according to economic areas.

Compared to earlier prognostications, within the past decade trends of forecasts as to the development and geographical location of smelter aluminium facilities have undergone substantial changes.

In 1980-83 aluminium smelter capacities of the world by 1990 were estimated to be in the order of 22-28 million tons (8), (9), a figure expected to rise to some 28-32 million tons by the year 1995-2000 (9), (10). Taking latest trends of world economy into account, an estimated growth rate of 2-3% seems to be certainly more realistic than the ones of 5-7% forecasted earlier.

Along with these more conservative estimates, significant changes in the geographical location of smelters are anticipated. With the exception of Australia, their points of gravity are believed to be shifting towards developing areas. All prognostications agree that the share of developed countries /including Australia/ in world smelter production is to diminish, whilst that of the centrally planned economies is to remain basically intact. There is also general consensus as to the situation in Latin-America. By contrast, greatest discrepancies are to be found in forecasts relating to the developing countries of Africa and Asia. Two extreme views in this respect are presented in Tables 1 and 2, while Table 3 is a combination of these two.

Table 1.

Aluminium smelter capacities according to principal economic areas of the world (9)

/in '000 tons./

Group of countries	1980	1985	1990	1995
Developed countries	10,773	13,345	16,300	19,590
Centrally planned economies in Europe	3,137*	3,905	4,635	5,430
China	360*	500	800	1,150
Latin-America	837	1,530	2,630	3,815
Total	15,892	20,280	25,715	31,685

N.B. * Estimates

Table 3.

Share of different economic areas in world aluminium production

Per cent.

Group of countries	1980 actual (9) (10)	1990 forecast*	1995-2000 forecast*
Developed countries	68	63-56	61-53
Centrally planned economies including Yugoslavia and China	22	21-23	20-22
Latin-America	5	10-11	13-14
Other developing countries	5	6-10	6-11
Total	100	100	100

* Where two figures are given, the first refers to (10) and the second to (9) as per references

Table 2.

World production of aluminium (10)
/Millions of tons/

Economic area grouping	1970	1975	1980	1990	2000
Market economies of Western Europe	2,0	3,2	3,6	3,8	4,5
United States	3,6	3,5	4,6	5,0	6,5
Japan	0,7	0,9	1,1	0,8	0,8
Other developed market economies	1,2	1,2	1,7	2,5	3,2
Developed market economies total	7,5	8,8	11,0	12,1	15,0
Latin America		0,2	0,8	2,4	3,6
Oil producing countries		0,3	0,4	0,7	0,9
Latin America and oil producing coutries total		0,5	1,2	3,1	4,5
Developing countries	0,5	0,5	0,6	1,3	2,3
European centrally planned economies x/		2,8	2,9	4,3	4,9
China and other centrally planned economies x/		0,3	0,4	0,7	1,3
Centrally planned economies total x/	2,3	3,1	3,3	5,0	6,2
Total	10,3	12,9	16,1	21,5	28,0

N.B. x/ Estimate

The establishment of smelters in a given geographic area may have advantages and disadvantages. As far as developing countries are concerned, these may be summed up as below:

Advantages

- Utilization of considerable but as yet untapped hydroelectric power potential
- Proximity of transport routes /sea, river, overland/ and possibilities of locating alumina plants close to high-grade bauxite resources in the tropics
- Strong moral and/or financial support by government agencies in implementing projects
- Availability of large and inexpensive local manpower resources to implement projects
- Incentives for pooling resources by developing countries with bilateral and regional cooperation in its wake
- Incentives for creating a local semi-fabricating and fabricating industry along with establishing other types of local industries

Disadvantages

- Extensive infrastructure costs calling for higher capital investment
- Long-distance transport of operating equipment; thereby more difficult and costlier maintainance
- Changing the lifestyle of local population, hitherto not familiar with industrial labour; this calling for increased amount of training
- Risks due to unstable political and economic atmosphere
- In case of limited domestic market, stronger marketing efforts abroad with possibilities, in turn, of raising domestic demand

2.2 Present status and future prospects of aluminium smelter operations in developing countries until the year 2000.

2.21 Primary aluminium production

According to available literature (8), (9), (10) the 1980-81 aluminium smelter capacities of developing countries are in the order of 1.8-2.2 million tons per year, corresponding to about 11-14% of today's world capacity. According to the same sources by 1990 they are expected to reach the 3-4 million ton mark, i.e. 14-18% of world smelter aluminium capacity /See Table 4/.

Table 4.

Aluminium smelter capacities of developing countries (9).

/in '000 tons./

Country	1980	1990
Brazil	278	746
Surinam	66	66
Venezuela	330	400
Mexico	90	90
Argentina	140	140
Ghana	200	200
Cameroon	58	58
Algeria	-	127
Egypt	133	166
Libya	-	120
Bahrein	125	250
Dubai	80	135
Iran	45	45
India	337	576
Indonesia	45	225
Total	2,027	3,493

One of the forecasts even predicts the total aluminium smelter capacities of developing countries to be in the order of 6.8 million tons by 1995-2000, which would be 21-24% of total world aluminium capacity prognosticated for the turn of the century (10) . As a reason for this, a further reduction of smelter operations in Japan due to shortage of energy and a slowdown in the momentum of expansion in Australian smelters caused by insufficient labour and cheap energy is assumed.

2.22 Foreign trade in aluminium.

In Table 5 a comparison of primary aluminium production with consumption is given in respect to the most significant areas of the world (9). It will be observed that in 1980 countries of the European Common Market, and on the Asian continent Japan and China, had been the largest metal importers of the world. On the export side, the largest source of supply had been, next to Latin-America and Africa, in North America Canada and in Europe the countries of centrally planned economies. By the end of the century, however, next to the developed countries of Europe and China, North America, too, is going to be a major metal importer, while Australia, Latin-America and Africa may account for the largest quotas of primary aluminium exports in the world.

Table 5.

Aluminium smelter production /P/ and consumption /C/ of the world compared, according to principal economic areas (9)

/in '000 tons/

Country or region		1980	1985	1990	1995
North America					
	P:	5,722	6,750	8,000	9,450
	C:	5,028	6,780	8,530	10,300
	Balance:	+ 694	- 30	- 530	- 850
European developed countries excluding such of centrally planned economy					
	P:	5,320	4,275	5,155	6,160
	C:	3,760	4,582	5,820	7,140
	Balance:	- 240	- 307	- 665	- 980
Japan					
	P:	1,091	950	1,000	1,050
	C:	1,709	2,150	2,750	3,390
	Balance:	- 618	- 1,200	- 1,750	- 2,340
Countries of centrally planned economy in Europe					
	P:	3,137	3,905	4,635	5,430
	C:	2,940	3,635	4,455	5,380
	Balance:	- 220	- 290	- 320	- 390
Latin-America					
	P:	837	1,530	2,630	3,915
	C:	563	900	1,385	1,915
	Balance:	+ 276	+ 630	+ 1,245	+ 2,000

Country or region		1980	1985	1990	1995
Africa					
	P:	587	870	1,200	1,430
	C:	196	310	450	610
	Balance:	+ 391	+ 560	+ 750	+ 820
China					
	P:	360	500	800	1,150
	C:	580	790	1,120	1,540
	Balance:	- 220	- 290	- 320	- 390
India					
	P:	285	300	400	500
	C:	276	365	475	600
	Balance:	+ 9	- 65	- 75	- 100

When an aluminium smelter is erected in a developing country one or more of the large multinational aluminium companies are usually co-proprietors in such ventures, their holdings being as a rule repaid by aluminium shipments. In the course of this, frequently various regional enterprises or combinations of financial interests may arise using or purchasing aluminium ingots or continuous-cast stock to operate local or nearby semi-fabricating industries. A case in point are aluminium shipments by ALBA, a smelter owned by Bahrain Aluminium Company /BALCO/ in the Middle East, which is dispatching about 30% of its exports to subsidiaries in the Middle-East manufacturing extrusions, cables and other products, and 60% to the

Far East. The remaining 10% is taken up by customers in South-East Asia, India and Europe. It is believed that by 1995-2000 the major part of such ingot exports are to be replaced by semi-manufactures.

By now continuous-casting technologies have almost universally been accepted. Such equipment for manufacturing rod wire and strip has become an integral part of casting shops located next to smelters, a fact to be remembered when the installation of new or the expansion of existing semi-fabricating plants is envisaged. This shift in technology is also to a large extent governed by financial considerations. Earnings by the sale of continuously-cast items is 1.12-1.25 times higher than those of aluminium ingots, the figure for rod wire being 1.15 in average, and that for coils of wide strips 1.20-1,25.

Present world trade in aluminium semi-manufactures roughly amounts to 1.6 million tons, of which developing countries may account for imports of about 325,000 tons. These figures do not include export shipments by the Soviet Union and other countries of centrally planned economy (6) .

A breakup of 1978 semi-manufacture imports to developing countries according to principal technologies was estimated in terms of percentages to be as follows:

Slabs and billets	40%
Rolled products	30%
Foil	10%
Extruded products	5%
Conductors	15%
Total:	100%

Some 25-30% of imports by developing countries are received from developed countries; the major part of the rest may be accounted for by import transactions under various inter-regional arrangements by the developing countries themselves.

If in a developing country the possibility of establishing an aluminium-processing industry, and within it, as the case may be, also the installation of semi-fabricating capacities is considered, as a first step it is necessary to take stock of that country's geopolitical situation, domestic resources and general standard of economic development. These are essential factors in determining the size and type of project whose implementation may be techno-economically feasible. Faced with a multiplicity of patterns, of course no universal formula may be devised to answer such questions. However, while each case has to be treated individually, certain alternative models of technical development do emerge which may serve as a guideline to decision makers when it comes to selecting type, magnitude and schedule of a project that seems to be realistic for a given country. These models will be dealt with at some length in this study.

A definition of what is considered a semi-fabricated product in this study may be found in sub-chapter 3.1.

2.3 Different models of technical development in the semi-manufacturing field.

To develop a semi-fabricating industry is a complex matter governed by a combination of geographical, political and technical circumstances. A few of these are enumerated below:

- The general standard of economic development in a given country; its population, infrastructure and energy supply
- Availability of local manpower; its intelligence, docility and diligence; the possibility of stationing foreign specialists for some months or years
- The raw material situation on site
- Present status of local raw material manufacture, if any, and its future potentialities
- The ownership of available aluminium raw material producing facilities; /whether a subsidiary of a multinational or run by local or regional capital/
- Foreign trade prospects; possibilities of regional long-term agreements; outlook of exports to industrially developed countries
- Magnitude and potential of the domestic market; how an envisaged project may fit into the general pattern of the country's economy, etc.

Although an efficient semi-fabricating industry calls for complex and up-to-date equipment, envisaged projects are not only governed by marketing considerations, but also whether or not adequate utilisation of equipment can be ensured and funds are available for their implementation /e.g. in the case of installation of modern strip-heat-treating lines, a high-duty hot strip mill, etc./. The purchase of less costly equipment only /e.g. that of a continuous strip-casting machines/ however, frequently tends to reduce the range and to impair the standard of available products, imposing limitations on their marketing /e.g. items of commercial quality to be disposed of at the domestic or regional markets only/. In each of the cases economic feasibility is a consideration of paramount importance.

In view of the above, the present study is discussing three alternative models of technical development on the understanding that numerous variants within these permit an almost unlimited number of combinations. The three basic technical development models hereafter dealt with have been chosen in such a way that the technological variants described in sub-chapters 3.3 - 3.9 may closely fit into the framework of any of the three basic alternatives, irrespective of what conclusions may in each case be reached after considering the overall effect of favourable or detrimental factors involved.

2.31 The traditional model

In dealing with this alternative, first of all the already existing finished product fabricating facilities have to be taken into account so far these more or less smaller enterprises have exclusively been using imported semi-manufactures. As a first step, consideration has to be given how to replace at least part of such imports by locally manufactured semi-fabricated products. Available capital, the general standard of manpower, inadequate infrastructure, industrial pattern and limited domestic market may be negative factors limiting the size of a planned new plant. In developing countries, therefore, at this stage, preference is usually given to installing various moderately-priced small-capacity target equipment easy to handle for the manufacturing of a relatively small range of well-marketable items. Such equipment, as a rule, is capable of performing only the final operations of semi-manufacturing, with the feed-stock /e.g. coils of hot-rolled strip, rod wire, etc./ being imported from abroad.

Advantages of such plants:

- Manufacture on a modest scale; the available capacities easily adaptable to actual market demand
- Relatively small amount of skilled labour required
- Small capital investment involved, especially if effectively operating second-hand equipment may be installed.

Disadvantages of such plants:

- Limited product mix usually of poorer quality
- Relatively low productivity of labour, coupled with poor specific energy efficiency.

In view of the pros and cons outlined above, it may be recommended in such cases, to start with the manufacture of extruded products / (7) and sub-chapter 3.5/. If justified by domestic demand, conductors /sub-chapter 3.6/, as well as sheets and discs of medium thickness and commercial quality may be produced. Further items of somewhat higher finish may also be considered, such as corrugated aluminium sheets manufactured by roller lines, or claddings and components of buildings made by mechanical folding or by using roller lines /see also sub-chapter 3.8/. An important equipment in producing such products is also a slitter for slitting and edging the imported wide strip coils.

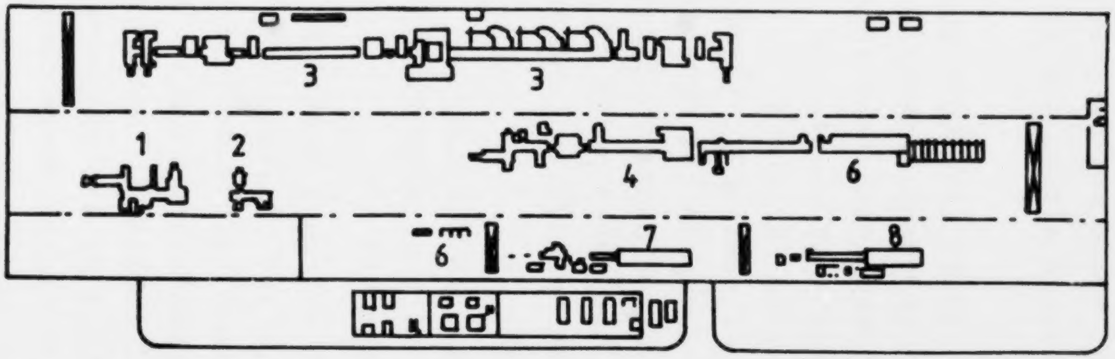
The manufacture of more sophisticated rolled products /foils and thin strips/ calls for a great deal of experience even if not the latest equipment is used. Therefore the manufacture of these may only in exceptional cases be recommended within the framework of this model.

In discussing this model, a brief reference has also to be made to the recycling of scrap arisings. When designing and installing an aluminium semi-fabricating plant of even modest capacity /say about 1000 tpy/ it is expedient to make provisions for the effective remelting of scrap on site /see Fig.13/. If melting the metal or remelting the scrap is not done in an effective way, this may involve losses varying from 5 to 30%. On the other hand, the sales price of poor quality remelted metal - may be smaller than one-third of that of the primary metal.

A concrete example of how such a facility may be established in combination with an extrusion plant is given in the relevant references (11) .

The raw material from which extruded sections, profiles and tubes are made is the billet. Billets are furnished either by the smelters or made by the extrusion plant itself on site. Extrusion plants are usually independent separate units sometimes of relatively small capacities. Geographically, their reliance on the smelters is less marked than is the case with plants where continuously cast strip and rod wire are further processed to final shape.

In Fig.1 the model of a traditional plant is demonstrated. Originally, it was an old-fashioned sheet rolling



1-Slitter I; 2-Slitter II; 3-Coil-coating line ; 4-Cutter; 5-Sheet profiling line; 6-Strip-profiling line; 7-Tube-Welding line I ; 8-Tube-Welding line II.

Fig. 1. Strip finishing shop (Annual capacity: 5 000 - 10 000t)

mill. Later a shop for manufacturing rolled products of higher finish and a small-capacity simple scrap-remelting unit were added. Of course, each of the production lines illustrated may be located separately.

2.32 Smelters as semi-fabricating operators

In a second model, aluminium smelters are acting also as manufacturers of certain semi-fabricated products. This development is due to the worldwide acceptance of continuous-casting techniques in producing rod wire and wide strips /3.322/. Smelters may thereby become an integral part of the semi-manufacturing field, especially as far as initial operations in producing various feed-stock items are concerned.

The minimum feasible annual capacity both of a continuous rod-wire and strip casting unit is 10,000 tons. Several such relatively small capacity lines may be installed in a parallel manner next to each other to be directly and continuously fed by molten metal from the smelter. For this end, only pure metal has to be used, treated with special care to eliminate impurities. Notwithstanding the obvious attractions of this technology, on the debit side there is the fact that only a limited range of semi-manufactures may be produced by it.

An example of how a semi-fabricating facility dependent on continuously-cast products received from a smelter may be operating is given in Fig.2.

As a rule, processing of the feed-stock furnished by the smelter is done in entirely separate locations and premises. Hence major aluminium companies operating

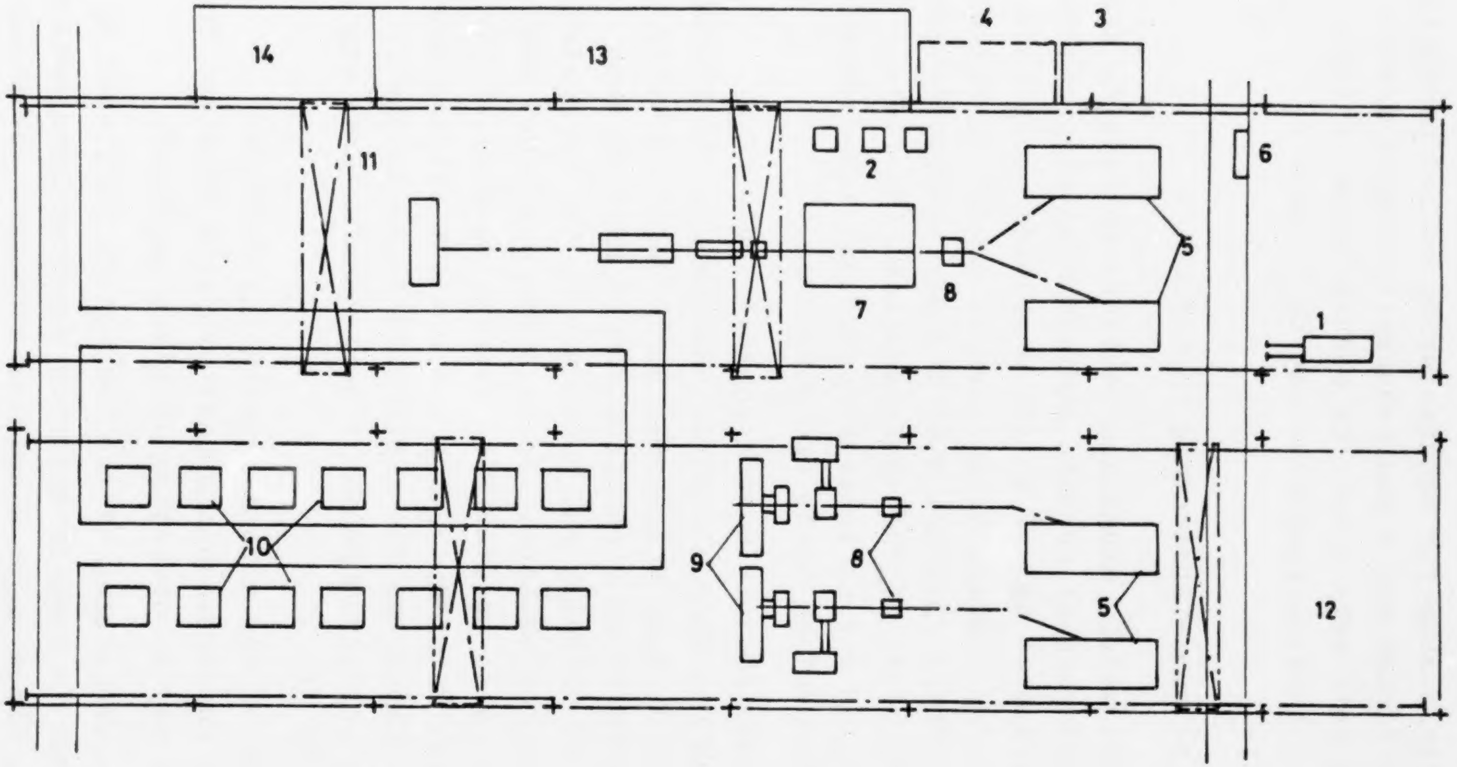


Fig. 2. Casting shop with continuous casters for wide strip and wire rod (wide strip: 25 000 tpy ; wire rod 20 000 tpy)

Fig.2

1 Tool Preheating Furnace
2 Slag Crucible Preheater
3 Liquid Chlorine Tank and Evaporator
4 Luquid Nitrogen Tank and Evaporator
5 Casting Furnace, 25-t
6 Road Weigh-Bridge
7 Continuous Wire Bar Casting Equipment
8 Continuous Metal Cleaning Unit, e.g. Union Carbide SNIF
9 Continuous Wide Strip Caster, e.g. JUMBO 3c
10 Coil Storage Racks
11 20/5 Mp-Capacity Bridge Crane
12 Scrap Storage Area and Storage for Auxiliary Materials
13 Offices and Social Units
14 Maintenance Work Shop

aluminium smelters have a vested interest in promoting the installation of such latter type of capacities as well.

Apart from some developing countries with a large population and strong domestic market, in other developing areas aluminium semi-manufacture supply has to be regionally organized virtually on the same lines. /E.g. meeting the local semi-manufacture demand of Middle East countries and Pakistan by the processing of products shipped from the smelters of Bahrein and Dubai; smelter operations in Argentina acting as an indirect incentive for developing semi-fabricating facilities in other Latin-American countries/.

2.33 Erecting of independent, complete semi-manufacturing complexes.

The third model envisages the establishing of a semi-fabricating complex, fully independent from a smelter, with a slab and billet-casting shop of its own, engaged in the manufacture of a full or limited but extensive range of items, operating in an area where potentialities of a diversified aluminium end-using industry exist at home and/or in a not too distant country, and where a sufficient volume of metal is available or may be obtained to run the facility. A case in point is a semi-fabricating plant built in the 1970s in Brazil for the manufacture of rolled and extruded items, as well as of foils (12) /see also Fig.3/. The project is implemented in several successive stages. In the first stage 12,000 tons of rolled products are being manufactured; of these 5,700 tons are strips, sheets, welded tubes, plied profiles and painted strips; of the 6,300 tons of foil manufactured 2,000 tons are of higher finish. Material to be rolled is furnished by two 1,600-millimetre wide continuous-casting machines. There is also a 16 MN earlier extrusion press and a billet-casting shop to feed it. After completing the last stage of the project, the rolling capacity is to be 50,000 tons per year. By that time, raw-material will be furnished partly by continuous-casting units and partly by slabs produced in conventional casting shops. To deal with high-strength alloys difficult to process, a separate hot-rolling stand is to be installed. At the same time, all auxiliary equipment and the extrusion plant too is to be expanded.

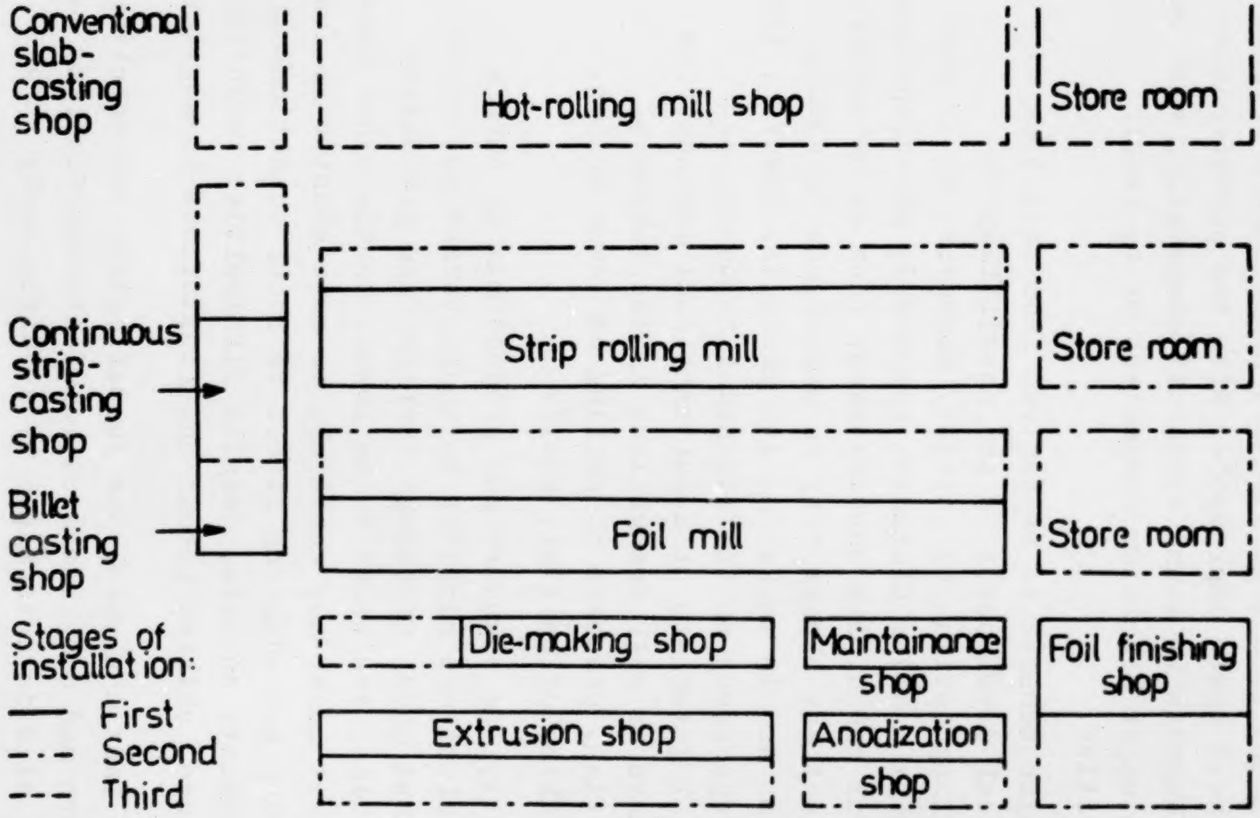


Fig. 3. Layout of complete semi-manufacturing complexes [12]

The erection of a complex like this calls for a developed infrastructure, skilled manpower or labour that may be suitably trained, and, of course, for a significant amount of capital. Hence such a project is in most cases implemented with the participation of a financially sound syndicate cooperating with one of the major aluminium companies, or by local authorities.

The major benefit to be derived from this type of technical development is the possibility of installing optimum capacities. Moreover, if in such a complex a major aluminium company is participating or it is one of its subsidiaries, from such quarters the plant may always rely on assistance in running business and in marketing its products. However, too much dependence on the financial resources and tactical interests of a multinational may have its drawbacks as well /reductions in the volume of production, pressure of selling at lower prices, reshuffling of capital, etc./.

No doubt, the standard and product mix by such a large plant are superior to those turned out under the first model discussed earlier, and production costs, too, are bound to be lower. On the other hand, the first model may certainly be more elastic in faster following and adapting itself to local conditions and developments on site, despite difficulties in infrastructure, skilled labour and limitations in capital.

In the last analysis, the justification for erecting a modern and complete semi-manufacturing facility of larger size is determined by a sufficiently large domestic and/or export market which may exist or may be created. To meet the demand effectively, the quality of items produced have to be up to international standard and market expectations /see Chapter 4/. Notwithstanding a few special items or group of products, smaller plants such as discussed in the first model would hardly be able to meet such demand.

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3. THE INSTALLATION OR MODERNIZATION OF EQUIPMENT FOR CERTAIN PHASES OF THE SEMI-MANUFACTURING PROCESS, WITH SPECIAL REGARD TO DEVELOPING COUNTRIES

3.1 General information on semi-manufactures

The first major phase in processing metal received from the smelters is the manufacture of semi-fabricated products.

Semi-manufactures are intermediate products of such shape and metallurgical properties which are almost exclusively mass-manufactured for being assembled or combined with other materials to be fit for direct use by the consumer.

According to their exterior shape, such semi-fabricated items may be classified as follows: plates and sheets, strips, discs, foils, sections, rods, tubes, wires and forged products. They have either a normal natural surface or are coated for reasons of protection against corrosion and/or decorative purposes with colourless or coloured organic or inorganic films.

An identical shape may sometimes be arrived at by different technologies: e.g. a piece of aluminium by forging or casting, a tube by extruding and/or drawing or by welding a rolled strip, or a rod wire by continuous casting or extrusion.

As a rule, by looking at its shape and surface it may be essentially said by what technology a product has been manufactured. However, by investigating its properties with the aid of modern /e.g. metallophysical/ test methods, this may be ascertained with full accuracy.

In 80% of the cases the cast material from which a semifabricated product is manufactured is undergoing some sort of plastic deformation. Furthermore, in order to obtain its desired final properties, also heat-treatment process/es/ has /have/ to be applied.

Fig.4 is a simplified flow-sheet of the most essential semi-manufacturing operations.

Most of the aluminium processed is used in an alloyed state. Alloying means that to metal of e.g. 99.5% average aluminium purity a certain percentage of another metal or several other metals has to be added so that a desired combination of properties may be arrived at /e.g. a certain mechanical strength combined with good corrosion-resistance, or a certain mechanical strength combined with high electrical conductivity, etc./.

Technological progress and pressure of demand have by now permitted to keep the tolerances of such alloying constituents within the bounds of 0.1%. The presence of impurities may even be measured in traces with accuracy of 0.0001%. Thus, what in everyday parlance is termed as non-alloyed aluminium, is actually an alloyed one from a technological point of view.

Depending on whether its mechanical strength obtained in the process of plastic deformation may be further enhanced by heat-treatment, an aluminium alloy may be graded as age-hardenable or non age-hardenable.

In Fig.5 the basic composition of the most currently used aluminium alloys is demonstrated. In highly industrialized countries - depending on the eventual end-use and other circumstances - some 20-40% may be accounted for as "non-alloyed" aluminium usage against 60-80% of what is termed

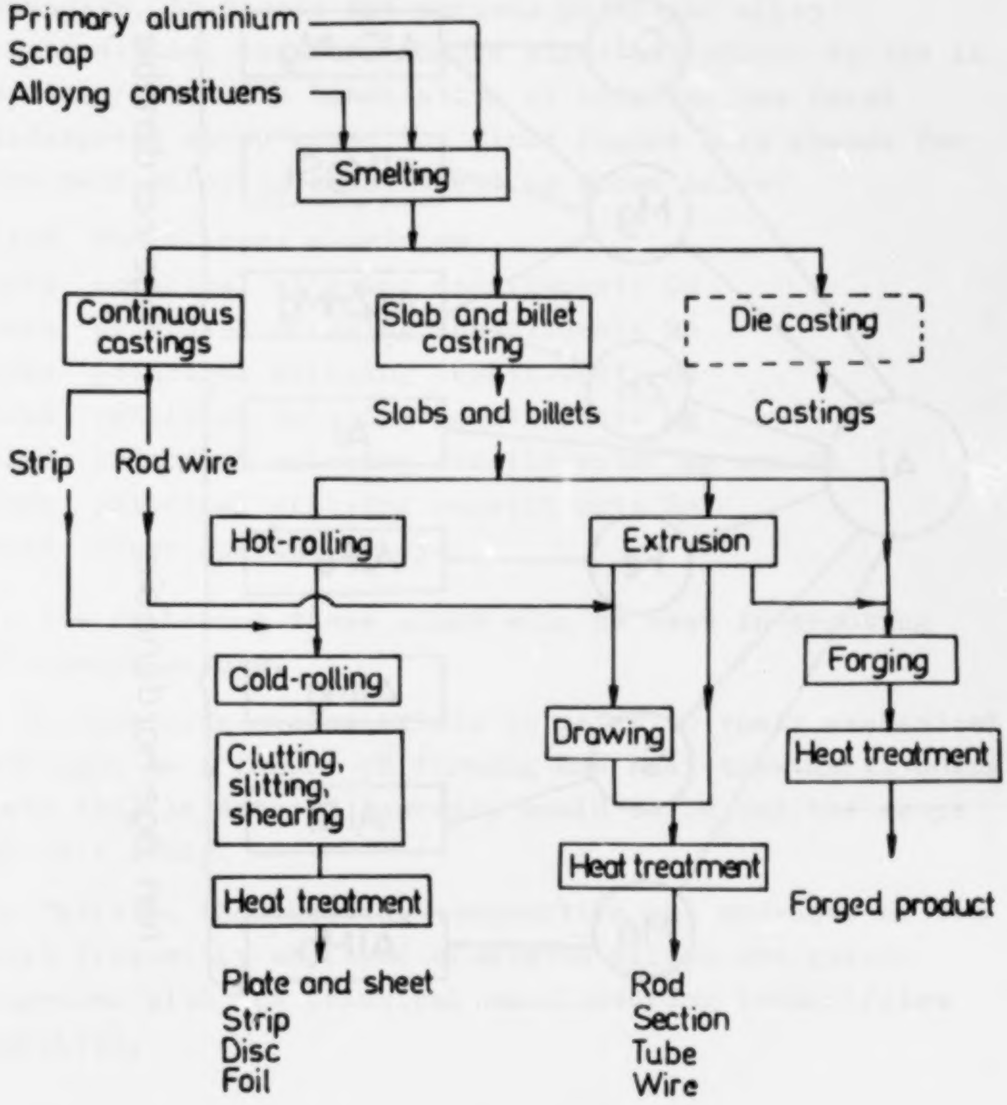


Fig. 4. Principal technological operations and products of semi-manufacturing.

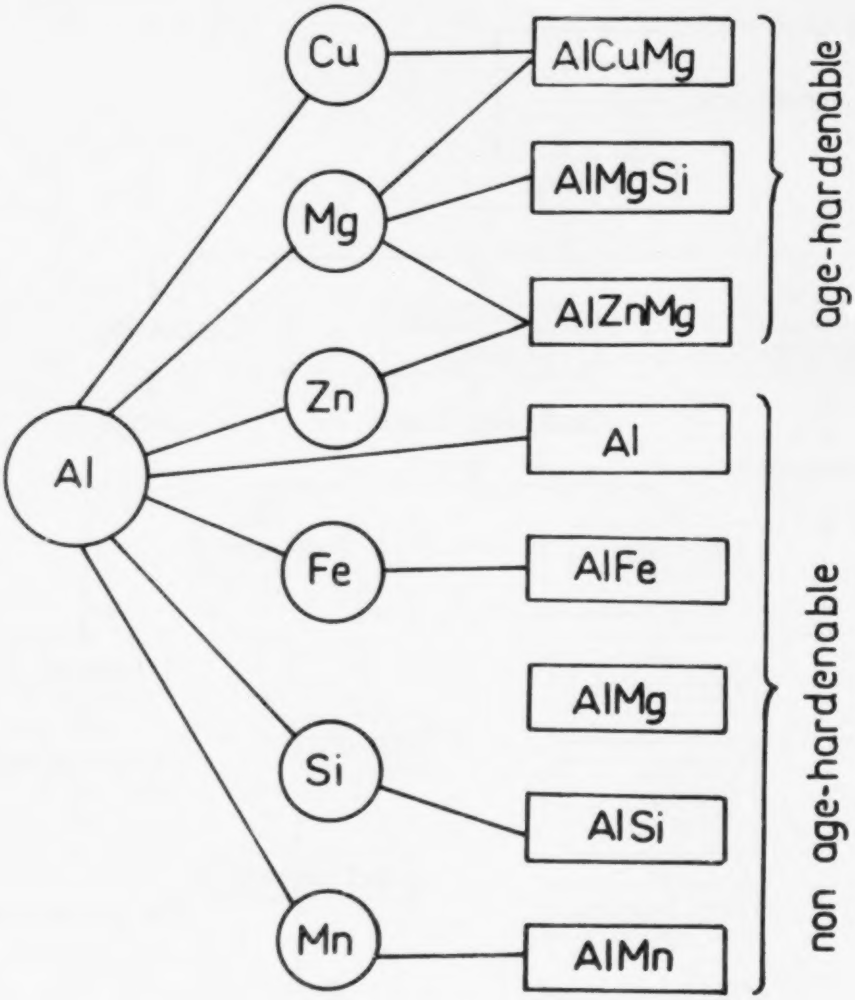


Fig.5. Principal aluminium alloys and their main alloing constituents.

as aluminium alloys. Of the latter, 20-40% are age-hardenable alloys, a larger proportion of these is used in extrusion plants than in rolling mills.

Nowadays, to denote the various principal alloy combinations, the four-figure signs introduced by the AA system /Aluminium Association of America/ has found widespread acceptance. The first figure here stands for the main alloying constituent as shown below:

1xxx	non-alloyed aluminium
2xxx	principal alloying constituent: Cu
3xxx	principal alloying constituent: Mn
4xxx	principal alloying constituent: Si
5xxx	principal alloying constituent: Mg
6xxx	principal alloying constituents: Mg and Si
7xxx	principal alloying constituent: Zn
8xxx	other special alloys

In the following these signs will be used in denoting aluminium alloys.

A similar code-system exists to refer to their mechanical strength as a result of forming and heat-treatment. Going into this in detail, however, would be beyond the scope of this study.

In Table 6. the chemical composition and end-uses of the most frequently employed aluminium alloys are given, together with the principal manufacturing technologies involved.

Table 6

Chemical composition of the most frequently used aluminium alloys

AA number of the alloys	Mg	Si	Cu	Mn	Fe	Zn	Ni	Ti	Cr	B	Special in-structions	Other contaminations Singly	Other contaminations Together	Al	Principal technology of manufacture	Principal end-uses
1050A	0,05	0,25	0,05	0,05	0.40	0.07	-	0.05	-	-	-	0.03	-	99.5	Rolling	Deep-drawing
1235	0.05	Si+Fe 0.65	0.05	0.05	Si+Fe 0.65	0.10		0.06	-	-	-	0.03	-	99.35		Foil
1200	-	Si+Fe 1.0	0.05	0.05	Si+Fe 1.0	0.10	-	0.05	-	-	-	0.05	0.15	99.00		
1100	-	Si+Fe 0.95	0.05 0.20	0.05	Si+Fe 0.95	0.10	-	-	-	-	/1/	0.05	0.15	99.0		Plating materials
2017A	0.40 1.0	0.20–0.8	3.5–4.5	0.40 1.0	0.7	0.25	-	-	0.10	-	0.25Zr+Ti	0.05	0.15	rest	Extruding Rolling Forging	High-strength structural material
2024	1.2–1.8	0.50	3.8–4.9	0.30–0.9	0.50	0.25	-	0.15	0.10	-	/2/	0.05	0.15	rest		
3003	-	0.6	0.05–0.20	1.0–1.5	0.7	0.10	-	-	-	-	-	0.05	0.15	rest	Rolling	Deep-drawing
3005	0.20–0.6	0.6	0.30	1.0–1.5	0.7	0.25	-	0.10	0.10	-	-	0.05	0.15	rest		Manufacture of holloware
3004	0.8–1.3	0.30	0.25	1.0–1.5	0.7	0.25	-	-	-	-	-	0.05	0.15	rest		Claddings
5005	0,50 1.1	0.30	0.20	0.20	0.7	0.25	-	-	0.10	-	-	0.05	0.15	rest	Rolling	Claddings
5052	2,2 2.8	0.25	0.10	0.10	0.40	0.10	-	-	0.15–0.35	-	-	0.05	0.15	rest		Venetian blinds
5754	2.6 3.6	0.40	0.10	0.50	0.40	0.20	-	0.15	0.30	-	0.10–0.6Mn+Cr	0.05	0.15	rest		Structures
5056A	4.5 5.6	0.40	0.10	0.10–0.6	0.50	0.20	-	0.20	0.20	-	0.10–0.6Mn+Cr	0.05	0.15	rest		Shipbuilding
6005A	0.40 0.6	0.6–0.9	0.10	0.10	0.35	0.10	-	0.10	0.10	-	-	0.05	0.15	rest	Properzi	Window and door frames
6063	0.45 0.9	0.20 0.6	0.10	0.10	0.35	0.10	-	0.10	0.10	-	-	0.05	0.15	rest	Rolling	
6082	0.6–1.2	0.7–1.3	0.10	0.40–1.0	0.50	0.20	-	0.10	0.25	-	-	0.05	0.15	rest	Extruding	Claddings
6101	0.35–0.8	0.30–0.7	0.10	0.03	0.50	0.10	-	-	0.01	0.06	-	0.03	0.10	rest	Forging	Conductors
6181	0.6–1.0	0.8–1.2	0.10	0.15	0.45	0.20	-	0.10	0.10	-	-	0.05	0.15	rest		Structures
7020	1.0–1.4	0.35	0.20	0.05–0.50	0.40	4.0–5.0	-	-	0.10–0.35	-	/3/	0.05	0.15	rest	Extruding	Structures
7075	2.1–2.9	0.40	1.2–2.0	0.30	0.50	5.1–6.1	-	0.20	0.18–0.28	-	/4/	0.05	0.15	rest	Forging	
8011	0.05	0.50–0.9	0.10	0.10	0.6–1.0	0.10	-	0.08	0.05	-	-	0.05	0.15	rest		Pilver-proof closures

N.B. A single figure for chemical constituents meaning maximum. Explanation of other signs of reference:

/1/ Max 0.003 Be for welding electrode and wire

/2/ On agreement by manufacturer and buyer Zr+Ti max.0.20 for extruded and forged products

/3/ 0.08–0.20 Zr, 0.08–0.25 Zr+Ti

/4/ On agreement by manufacturer and buyer Zr+Ti max.0.25 for extruded and forged products

3.2 Pattern of aluminium consumption in developed and developing countries and changes to be anticipated until the year 2000

However different this pattern between developed and developing countries now may be, in planning long-range technical development in this field the relevance of the existing pattern in developed countries may not be underestimated by and have to serve as useful guidance for the future to developing countries. In Table 7 a breakup of aluminium usage for some selected countries and areas is given according to end-uses.

It will be observed that throughout the countries and areas under review transport is accounting for one of the largest percentages of end-use. Indeed, this is a sector where many of the salient advantages of the metal may be put to optimum use: small density, good mechanical strength, ease of forming and high corrosion resistance. Owing to the high price of oil, nowadays throughout the world great savings in the use of fuel are striven for, prompting the vehicle manufacturing industries to use increasing volumes of aluminium, a trend of special interest to both developed and developing countries, expecting to perpetuate.

Another major end-using sector is electrical engineering especially in the field of manufacturing conductors. In developed countries it may account for an average of 10% of aluminium usage. In developing countries, presently and in the foreseeable future , it constitutes the largest share of aluminium usage. /E.g. in India 50% of total aluminium consumption/. The reason for this is that in developing local industries and infrastructure electrification and the installation of electric power transmission grids are

Table 7.

Breakup of aluminium usage in a few selected countries and areas (1)

Per cent

Sector of end-use /according to the technology of European Aluminium Statistics	European market economies 1976	USA 1977	Japan 1979	Hungary 1980	South Africa 1980	Brazil 1980	Argentina 1980	Egypt* 1980	India** 1979
Transport	20.2	22.7	21.2	7.9	7.8	19.2	13.0	4.0	10.0
General engineering	5.1	5.8	17.8	6.9	-	4.1	4.0	0	0
Electrical engineering	7.8	9.8	10.8	17.3	29.0	52.1	28.0	19.5	55.0
Building, construction	13.6	22.9	32.9	9.9	14.0	23.8	20.0	30.0	5.0
Chemical-, food and agricultural appli.	1.2	1.3	5.2	2.3	18.0	8.1	14.0	-	-
Packaging	7.3	21.1		5.4				1.0	1.0
Domestic and office appliances	6.3	6.8	1.9	2.9	15.0	14.6	6.0	45.5	20.0
Powder consuming ind.	0.5	0.8	-	2.7	6.0	-	-	-	-
Iron- and steel ind.	3.6	1.8	-			-	-	-	-
Metal industries not specified elsewhere	8.9	3.0	5.7	14.6	11.0	8.7	3.0	-	6.0
Miscellaneous				7.9					
Export of semis, foil, cable and powder	25.5	4.0	4.5	22.2	-	-	12.0	-	-
Total	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0

N.B. * only semis, ** estimate

indispensable prerequisites. In view of this, for a great length of time, the pattern of aluminium consumption in developing countries will be different from that of the developed countries. In this respect aluminium has no serious competition from other metals; the use of copper keeps on to be more and more costly and the world's copper resources tend to deplete in the long run.

Another sector with great aluminium potentialities is the building trade. Figures relating to aluminium usage in this field are less uniform. In Europe this market is not so developed as in the U.S. and particularly in Japan, although great strides are being made in using this metal in the manufacture of highly insulated window frames, wall curtains and banisters etc.

In respect of developing countries we cannot but agree with Kumar's prognostication of constantly increasing aluminium usage in the building construction industry (1), on the understanding, however, that intensification of aluminium usage in apartment houses and private homes may be anticipated only in countries of high per capita GDP /see Table 7/. In other developing countries such aluminium usage on a modest scale is likely to be limited to the building of industrial or agricultural premises. In the building construction field, anyway, competition from other structural materials /plastics, wood/ is believed to keep on to be strong both in developed and developing countries.

In the USA an exceedingly large volume of aluminium is used for packaging. Principal items in this connection are transport containers and drink cans. Some interesting facts seem to emerge from such aluminium usage, applicable also to other fields, viz.

- The smaller weight of aluminium transport containers eventually results in fuel economies
- Aluminium used in the manufacture of drink cans may repeatedly be recycled into the production process as scrap, permitting great economies in energy and thereby extra benefits.

In developed countries the significance of aluminium as a means of packaging is steadily growing. As far as developing countries are concerned, its share in terms of overall consumption is expected to be on a more modest scale, because some of its applications may still be considered in some way a luxury in developing areas /e.g. single-use throwaway cooking trays from foil strip/. There is,however, no getting away from the fact that in developing a truly competitive food-processing industry capable of exports, the use of attractive up-to-date packaging /e.g. such made from foils and combinations thereof, or inside-varnished outside-painted cans etc./ may not be dispensed with.

In packaging, aluminium is facing strong competition from other materials, in the first place from plastics. On the other hand, it does have unique properties: light- and heat-reflectibility, waterproofness, no toxic effects, etc. All these preserve the quality and aroma of foodstuffs for a long time. Aluminium, moreover, lends itself well for combination with other materials: plastics, paints, etc.

Some aluminium end-uses are insignificant in developed countries but are important in developing countries.

A case in point are cooking utensils and other mass-manufactured items. Simple aluminium holloware is fairly durable and inexpensive, suitable for use especially in countries where per capita GDP is low.

With geographic and climatic considerations in mind, it may be expedient for developing countries to utilize solar energy for water heating or to employ water-saving heat exchangers and irrigation systems in areas where water is scarce, or to establish desalination plants on the seashore. Considerable volumes of aluminium may be involved in such projects presenting further outlets for the metal.

In developing countries, too, efforts of boosting aluminium and raising the volume of aluminium consumption call - next to thorough market research - for a close examination of whether and how far design and the entire process of manufacture may do justice to the specific properties sought for in products whose manufacture is envisaged. Guidance as to such matters of techno-economic feasibility is given in a UNIDO publication entitled "The Economic Use of Aluminium" (2).

To link long-range consumption expansion targets with predictions of exactly what specifications of semi-fabricated products are to be needed is an almost unsurmountable task. However, a fair approximation of what principal types of semi-manufactures would be required by the sectors involved can be made as seen in Table 8.

Table 8.

Typical demand by several end-using sectors according to main branches of technology.

End-using sectors	Type of semi-manufacture				
	rolled	extruded drawn	wire	casting	forged
1. Transport	++	++		++	++
2. Electrical engineering		+	++		
3. Building	++	++		+	
4. Packaging	++	+			
5. Mechanical engineering	+	+		+	+
6. Agriculture	+	+		+	

Signs employed: ++ considerable demand
+ moderate demand

A breakup of such principal branches of semi-fabricating production in three different regions of the world is given in Table 9.

Table 9.

Breakup of principal branches of semi-fabricating production in percentages based on 1979 data.

Type of products	USA	Western Europe	Japan
Rolled	65.8	54.7	34.1
Extruded-drawn	23.4	33.0	57.4
Wire and cable	9.5	11.7	8.4
Forged	1.3	0.6	0.1

Evidently, the consumption pattern of a given country or region is dependent on a large variety of circumstances, including the prevailing domestic and world market situation as well as exports and imports in the area. Therefore no universal formula may be devised and suggested as to what semi-manufacturing pattern may be adopted by a given country or firm.

Reduction of production costs and overheads in relation to proceeds is a major consideration in installing new capacities or updating older ones and operating both. Market pressure for a constant improvement of product standards, too, may be a serious source of preoccupation.

The volume of metal available for operating a facility and the magnitude of the final development target envisaged may greatly influence the selection of a proper technology and type of equipment of reasonable capacity to be used in the venture effectively. E.g. in a rolling shop of medium size, the siting of a continuous tandem line with several stands would not be expedient because its capacity would be excessive and would be incompatible with those installed and operating economically in other parts of the plant.

Similarly, in medium-size extrusion plants to be erected in developing countries there is no point in installing a hydrostatic press, not only because of its great capacity, but also because the range of products manufactured by this complex and costly equipment /copper-plated aluminium busbars, wires, high-strength rods/ is rather limited.

Product development is an important objective in reducing production costs and in improving and permanently stabilizing the quality of products (3) .

Initiatives for product development are often forthcoming from the customers /e.g. changing the design of sections, pressure for thinner items or for such of higher mechanical strength or other properties, etc./. In order to keep its firm market position, the semimanufacturer has to meet his customer in promoting the optimum solution of such demands.

General actual trends as to the manufacture of semifabricated products, are believed to prevail until the turn of the century /of potential interest to developing countries as well/ and may be summed up as follows:

- In countries where semi-manufacturing plants are not suppliers of the armament industries about 50-60% of production are alloys; where they are suppliers of the armament and aircraft industries this share is 70-80%.
- To improve the properties of non-alloyed aluminium /e.g. electrical conductivity, susceptibility to forming and deep-drawing/ the magnitude and proportion of impurities is kept under strict control
- Product standards keep on to become increasingly stringent; utmost demands are set as to the permissible range of alloying constituents; exceedingly narrow tolerances of mechanical properties and gauge are allowed for
- There is a rising demand for products of higher finish /e.g. painted products, items ready for assembly, cut to measure and provided with borings or supplied in combination with fittings/.

3.3 Independent casting shops or such shops attached to smelters /treatment of the melt, slab and billet casting, continuous casting/.

The standard of a product is fundamentally determined by the quality of the raw material from which it is made. In view of this, particular attention has to be devoted by the semi-manufacturer to the study of the properties of the metal in the molten state, to improving casting technologies, to the design of equipment used for such ends, and to developing testing methods. Average properties of cast slabs and billets from which, respectively, rolled and extruded semi-manufactures are made, truly reflect the result of these efforts. Characteristic of the standard of such items are their

- chemical composition
- content of gaseous and solid non-metallic impurities, and
- quality of surface.

Chemical composition is generally determined by what the customer is ordering and by the relevant standard specifications called for. According to the latter, the actual concentration of most alloying constituents may vary within a range of 1.0-1.5%.

In order to produce items of more uniform quality, semi-manufacturers themselves usually reduce this range to 0.2-0.3%. To remain within such self-imposed more severe bounds, careful laboratory testing of the melts is necessary. /Use of different spectroscopes, determination of gas content, etc./. In producing alloys, there is nowadays a marked trend of using primary aluminium of as high purity as possible. The permissible amount of non-metallic impurities depends on the alloy to be produced and on the end-use of the semi-fabricated item to be manufactured. The most critical gaseous impurity is hydrogen. Depending on the type of alloy, its maximum amount may vary from 0.08 to 0.18 $cm^3/100$ grams of aluminium. For testing it, instruments based on the "first bubble" principle are widely used /e.g. one developed by Alusuisse called the "Aluschmelztester"/. The most important solid non-metallic impurity is aluminium oxide. Its permissible range in terms of oxygen is 5-30 ppm. Oxides may not be present in the form of coarse band-like nodes or inclusions. Purity called for is arrived at by a suitable melt-treating technology and by filtering the melt before casting.

3.31 Melting; treatment of the molten metal.

The initial charge used by a casting shop is either a cold one or in case of a casting facility adjacent to a smelter, molten metal. Using molten metal to begin with, is an energy-saving procedure, inasmuch as no remelting of the ingot is necessary. The difference in the initial charge has a marked influence on designing the equipment called for in a casting shop. When located next to a smelter, metal tapped from different electrolytic cells is transferred to and collected in special furnaces. This is where the desired composition of the melt is arrived at. The molten metal is thereupon passed on to a casting furnace and after suitable treatment ready for casting. Nowadays, casting shops next to smelters are engaged in the first place in producing slabs and billets or continuous-cast items. Only reduced volumes of so-called smelter ingots to be remelted are cast.

In casting shops using cold charges in preparing slabs and billets the situation is different. Here the proportion of primary aluminium and different types of scrap is controlled by technological instructions. For a higher quality product, only smaller amounts of thin scrap, turnings or secondary ingots derived from processing scrap may be added to the charge. In modern aluminium casting shops the melting of the charge and the desired composition of an alloy may best be taken care of by hearth reverberatory furnaces.

This type of furnace is the most suitable one to intensify melting and to produce a homogeneous blending of the charge, along with performing various purification processes as well. As a fuel, either gas or oil may be employed. In case of small capacities, electric energy /resistance or induction heating/ may be recommended. In addition to effective technology, the availability of suitable energy is of paramount importance. The size of the furnaces depends on the volume of production envisaged. A hearth reverberatory furnace may be designed to handle charges of 2-80 tons, a channel-type induction furnace such of 2-20 tons, and a crucible induction furnace 1-10 tons. It is advisable to have units of the largest capacities, because energy and other performance data of the latter are the best.

It is economical to feed the charge into a remaining bath. In case of humid materials or such prone to explosion, melting has to be started in an empty furnace. Charging of the furnace should be completed as quickly as possible. For this reason, furnaces are provided with large side-doors or removable tops. Large doors also permit easier manipulation of the melt. Gas- or oil-fired hearth reverberatory furnaces have a large melting capacity, i.e. 10-15 tons per hour. Their specific energy consumption averages 3.5 GJ/ton of aluminium. In latest advanced designs this figure has even been reduced to 1.9 GJ/ton. To enhance thermal efficiency, combustion-air is preheated to 450-500°C in recuperators. Burners of the furnaces are automated. Maximum bath temperature is 760°C; the velocity of discharged gases is 100 m/sec.; after preheating the combustion air, the heat of flue gases may be used for producing steam or for heating.

From the melting furnace the charge is transferred to the casting furnace. The most widely used are hearth reverberatory casting furnaces arranged in tandem with melting furnaces. Each melting furnace is connected to one or two casting units. The fuel is usually gas; electric energy or oil is less frequently used, because electric heating elements are sensitive to the vapours of metal-treating agents and oil is tending to pollute the charge. Melting furnaces should be of fixed, and casting furnaces of tiltable design.

Setting the composition of the charge and partial removal of non-metallic impurities are done in the melting and casting units.

To attain the desired metallurgical structure of slabs and billets, grain-refining additives are used. For this purpose, usually an Al-Ti-B master alloy is used. It is fed in form of 3-5 kilogramme ingots into the channel between the melting and casting furnace upon transfer of the charge, or right into the casting furnace. To feed the master alloy in form of a wire directly before the mould into the spout, is a more up-to-date and better solution. Then a minimum of 0.5-1 kg/ton of master alloy will be needed to obtain a good metallurgical structure. Master alloys are usually made in 1-3 ton crucible induction furnaces, where a uniform distribution of their content may be arrived at by the movement of the bath.

A melt of proper composition may in itself still be unfit for casting high-quality slabs and billets owing to being contaminated by gaseous and solid non-metallic impurities. These have to be removed either in the melting and casting furnaces, or - as a latest development - outside of these, between the casting furnace and mould, by various methods and with the aid of certain auxiliaries. The most frequently used methods of jointly disposing of hydrogen and oxides are as follows:

- Treatment by active gas /chlorine/ done either in the casting furnace or by an "in line" purifier after it. To reduce the harmful effects of chlorine, it is mixed with a neutral gas. The amount to be used is 1-4 kg/ton of aluminium
- Treatment by an active agent, generating chlorine, e.g. hexachlorine-ethane takes place in the casting furnace. Hexachlorine-ethane is added to the melt in form of pellets, or as a more recent development, in form of powder introduced by the help of an N_2 current. Specific consumption: 2-4 kg/ton of aluminium.

- At present and in the long run, continuous, combined processes seem to be the most effective processes to be recommended. As a special advantage, these treatments are taking place after the melt left the casting furnace, at a point nearest where it starts crystallizing; the total volume of the charge is purified in a uniform manner; the treatment consists of several simple steps easy to handle. The best known types are: the FILD process developed by British Aluminium, SNIF by Union Carbide (4) , ALPUR by Servimetal and MINT by Conalco.
- For mechanical filtering, glass-fibre fabrics and fine-meshed ceramic screens are used /e.g. a tube-shaped screen developed by Carborundum, or chromium trioxide and aluminium sheets combined with polyurethane as used in Conalco-purifiers/.

The efficiency of purification may be enhanced by traditional holding in the casting furnace. The length of this may vary from a few minutes to one or two hours. Keeping the charge at around casting temperature is only effective if the furnace is devoid of any vapour. This condition may best be met by employing electric resistance furnaces.

3.32 Casting.

The initial shapes and forms of aluminium from which semi-fabricated products are directly made are slabs for rolling and billets for extruding, as well as coils of continuous-cast strip and rod wire.

3.321 Slab and billet casting.

Size, uniformity of shape, surface and metallurgical structure of slabs and billets are basically determined by the process of casting. Throughout their cross-sections, slabs and billets have to be made up from uniform crystals, their numbers to average 400 per square centimetre.

On casting slabs and billets into conventional moulds, on their surface a 5-20 mm deep zone of a poor metallographic structure is forming which - especially in case of manufacturing high-quality /e.g. anodizable/ items- have to be mechanically scraped off, so as to produce a surface of good quality.

In order to eliminate the harmful effects of conventional semi-continuous casting on the structure and surface of billets, various "hot top" processes have been developed. Cases in point are e.g. the Air Slip method of Showa (5) and casting into an electromagnetic field (6) .

Accuracy to size and shape may be tested by measuring the cross-section and cut length of slabs and billets. E.g. the diameter-tolerance of a 200-270 mm dia. billet is ± 2 mm, and its tolerance of length ± 10 mm over a 600-1,100 mm length, with a maximum permissible arching of 2 mm per metre.

An important prerequisite of casting high-quality slabs and billets are good casting machines. If their capacities are not such as to permit the complete discharge of a furnace by a single operation or e.g. on casting small-diameter billets, the casting machines have to be fast enough to repeat several instances of casting. Up-to-date vertical casting machines are capable of casting slabs and billets of 7-9 m maximum length. The maximum number of casting e.g. 150 mm dia. billets is 72, and that of 450x2000 mm slabs 8. Vertical electromechanical casting machines were found to be the most reliable ones. Also the hydraulically-operated mould-table descending types have proved to be satisfactory, but they need twice as deep casting pits. Some publicity is given to horizontal casting machines. Their capacity is small, but the casting and the subsequent operations of casting: cutting, homogenisation, controlled cooling all form part of a single continuous cycle /Fig.7/. In small-capacity target-casting they may be used with advantage (7), although here the quality of billets is not up to that of the vertically cast ones. Successful efforts of automating the casting process are well known. In such cases speed is controlled by programming. The use of such equipment calls for a suitable industrial background and experience.

Fast and unbalanced crystallizing processes involved in semi-continuous casting tend to give rise to phase precipitations inside the crystals and producing mechanical stresses in the slabs and billets. Both are sources of inconvenience in the successive stages of processing. The uneven distribution of alloying constituents has a detrimental effect on the workability of the metal and on the surface of the finished products. Therefore slabs and billets are undergoing homogenisation after casting or have at least to be unstressed. For homogenisation, usually gas-fired or electric air-chamber type furnaces are used where the distribution of temperature is uniform. The magnitude of the charge may vary from a few tons to 60-80 tons. To save energy, homogenisation is sometimes jointly done with preheating preceeding the process of forming, if permitted by the capacity of the preheating furnace.

3.322 Continuous casting mills

Some 25-30 years ago a novel process was developed featuring a combination of casting and hot-rolling in a single operation: continuous casting. Since then, this technology has been significantly improved, making heavy inroads on the conventional method of casting followed by hot-rolling.

At an annual capacity of 40,000 tons, investment costs of the two technologies are equal. At lower capacities the establishment of a continuous-casting machine, at larger capacities that of a conventional facility is generally cheaper. A continuous-casting facility has the advantage that it may be installed in relatively small subsequent stages of 8-12,000 tons of annual capacity each. In terms of hot-rolled strip, its output is 10-15% higher, combined with savings of 30-35% in energy. By continuous-casting, narrow and wide strip as well as wire may be manufactured. /For the latter refer to sub-chapter 3.6./

There are two types of wide strip continuous casting mills: the first is producing strip of a thickness that may be coiled right away in a single operation, and the other is of a tandem arrangement casting thick strip to be subsequently hot-rolled. In the first case, the cast metal is freezing while passing through pairs of rolls to be eventually coiled, the resultant rate of deformation being 15-95%.

A fair range of metal may be processed in this manner from non-alloyed aluminium to alloys of medium Mg content, in thicknesses of 6-10 millimetres and widths up to 2,000 mm. Average outputs calculated on the basis of 1,000 mm wide strips are

1.8 ton per hour for 99.5% aluminium
1.1 ton per hour for the AlMg 1 alloy, and
0.9 ton per hour for the AlMg4 alloy.

Calculating a 1,300 mm wide strip, total annual output is about 10,000 tons. Capital expenditure, including building, may be estimated at Dollar 650,000 per 1000 tons of annual capacity. Equipment may be procured inter alia from the following firms:

Firm	Type
Pechiney /SCAL/ of France	3C, Jumbo 3C
Alusuisse of Switzerland	Caster I
Hunter of USA	Caster, Super-Caster.

Another type of equipment is featuring a water-cooled mould consisting of a mobile steel band fixed onto rollers and caterpillar-driven mould-members, in and between of which the 12-50 mm thick and 2,000-millimetre wide strip is freezing. The intermediate product thus arrived at is thereupon passed on to roll stands located behind the casting equipment for further reduction. Depending on the number of roll stands, the end-product may be of 2.5-12.0 mm thickness. The rate of hot-deformation in this case is 30-95%. The equipment is capable of dealing with practically any type of alloy. Its operation is at an annual capacity of 60,000-120,000 tons the most economical. The best known manufacturers, types and outputs thereof for strip-widths of one metre are (8) :

Firm	Material	Output
Hazelett of USA	99.5% aluminium	35 tons/hour
Alusuisse of Switzerland, Type Caster II	99.5% aluminium	20 tons/hour
	AlMg 4	4 tons/hour
Alcan /Canada/ Mark I.	99.5% aluminium	42 tons/hour

In manufacturing narrow strip and wire, casting is done between a water-cooled 1-2 metre dia. wheel and steel band enclosing it, the charge freezing along the perimeter of the wheel (8). The resultant strip is thereupon either coiled or rolled. Rod wire cast in a similar manner is given a number of passes by several rolling lines, to be reduced to gauges of 8-15 mm dia. /For further information refer to subchapter 3.6./ Capital expenditure, without building, may be estimated at Dollar 170,000 per 1000 tons of annual capacity.

A cast narrow strip is usually 15-20 mm thick and 100-400 mm wide. Such intermediate product is then reduced by one or two passes to obtain a gauge from which slugs may be cut, used in the manufacture of impact-extruded items /collapsible tubes, aerosol bottles, etc./. The operation of a plant specializing in the manufacture of such items may be economically feasible only if using 1,000-1,500 tons of slugs made from 2,500 tons of hot-rolled strip.

3.33 Installation of casting facilities

Production programmes and capacities of casting shops are governed by the selection and volume of semi-fabricated products whose manufacture is being envisaged. E.g. it is expedient to establish along a rolling-shop of 60,000 tons annual capacity a casting shop of 90,000 tons capacity per year to cater for the entire demand of the mill, including the remelting of arising scrap. The capacity of a casting shop, however, may be reduced to or below the volume of own scrap arisings /about 30,000 tons or less/ if the mill is prepared to buy the part of slabs from outside sources and to sell its own scrap. Capital expenditure involved in establishing a scrap and billet casting shop, including building, may be estimated to be in the order of Dollar 650,000 per 1,000 tons of annual capacity. Some 70-80% of this has to be accounted for by the purchase and installation of the equipment.

Such projects need not to be implemented in a single stage. Initial capacity may be expanded as demand is growing and sufficient capital is made available. In Fig.6 the layout of a conventional semi-continuous slab and billet casting facility is given, using cold charges to begin with.

Fig.7 is a layout of a 5,400-ton per year rated capacity 600 m^2 casting shop established in conjunction with an extrusion plant. The facility is suitable of producing medium-standard billets by using purchased primary ingot and scrap arising in the plant, in which one extrusion press is operating. The volume of the scrap is 1,000-1,500 tpy. Casting is done in combined melting and casting furnaces, to which a continuous horizontal billet casting machine and homogenisation unit is added. The total costs of erecting such a target casting shop are amounting to Dollar 200,000 per 1,000 ton of annual capacity, of which 70-80% is the sales price of equipment plus installation costs (7).

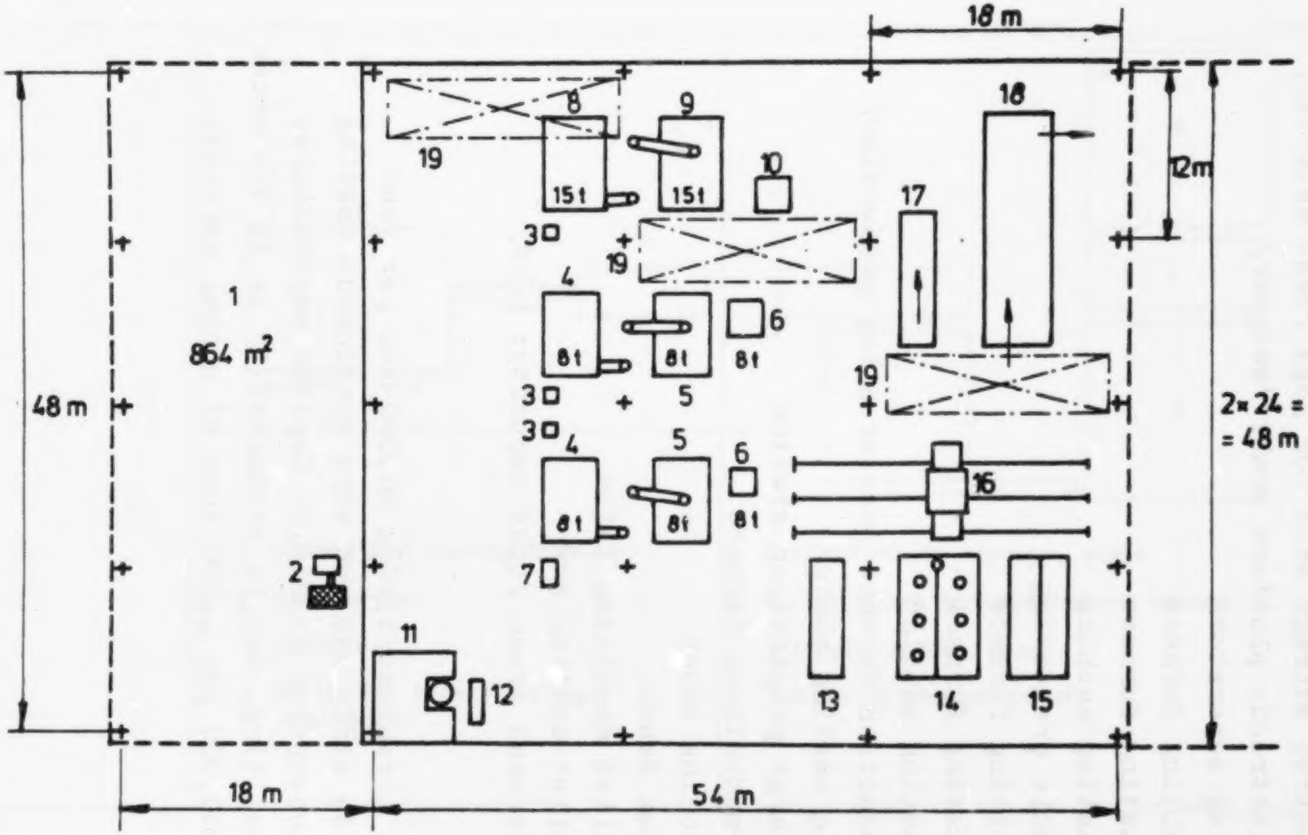


Fig.6 Traditional slab and billet casting shop with vertical casting machines (capacity 16 000 tpy)

Fig.6

1 Covered storage area for logs /base material/
2 Electronic platform scale /weigher/
3 Slag separator
4 Melting furnace
5 Casting furnace
6 Casting machine
7 Ladle preheating
8 Melting furnace
9 Casting furnace
10 Casting machine
11 Induction furnace /master alloy production/
12 Pig casting chain
13 Charge preparation station
14 Homogenizing furnace
15 Cooling bench
16 Push Bench
17 Billet machining lathe
18 Billet-cutting saw
19 Overhead crane /load capacity: 10 t/

The general arrangement of a 40,000-ton per year capacity wide strip and rod wire continuous casting mill is demonstrated in Fig.2. Capital expenditure, including building, may be estimated to be in the order of Dollar 500,000 per 1,000 tons of annual capacity.

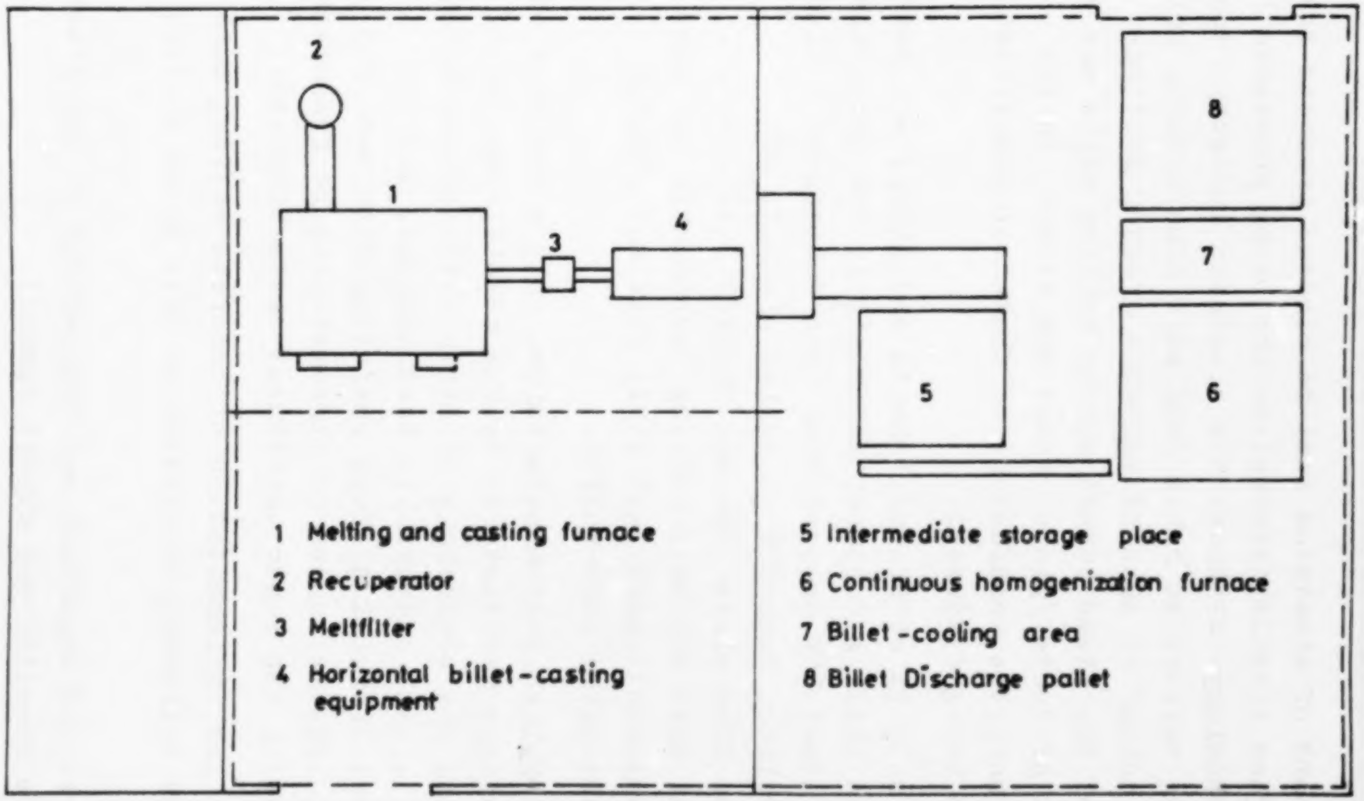

2
1
3
4
8
7
5
6
1 Melting and casting furnace
2 Recuperator
3 Meltfilter
4 Horizontal billet-casting equipment
5 Intermediate storage place
6 Continuous homogenization furnace
7 Billet-cooling area
8 Billet Discharge pallet

Fig. 7. Casting shop with horizontal billet casting machines (5400 tpy) [7]

3.4 Manufacture of rolled semi-fabricated products.

The major part of aluminium semi-fabricated products that have undergone plastic deformation are being processed by rolling technology. Although the aluminium industry, too, is employing calibrated rolls /rod wire manufacture, cold-rolling of tubes/ or such of variable grooved sections, up to 80% of the items turned out by rolling mills are so-called flat products /plate, sheet and strip/. In the following, only the manufacture of flat semi-fabricated products is being discussed.

Generally, only 5% of plates, sheets and strips are sold as so-called thick structural materials in the hot-rolled state, and about 95% as such that have subsequently also been cold-rolled. Some 85% of rolled products are manufactured from slabs /see sub-chapter 3.321/ by conventional hot- and cold-rolling technology, and some 15% from semi-continuous cast strip /see sub-chapter 3.321/ subsequently cold-rolled.

As for cold-rolled semi-manufactures, only a fraction of them is nowodays manufactured by the obsolete method of sheet-rolling the technology of strip cold-rolling having by now almost universally been adopted. The establishment of rolling shops operating with such outdated technology may under no circumstances be recommended, notwithstanding the lower investment costs involved.

Considering the implementation of concrete rolling mill projects the following circumstances have to be closely examined:

- What may be the magnitude and composition of the present and future domestic and export demand?

- What stages and schedule of expansion seem to be reasonable in view of such market demand?
- Where and how to obtain raw material for operating the project?

At the outset, when both the local aluminium industry and culture of domestic aluminium consumption are still in their infancy, the manufacture of a rather wide range of items has to be envisaged. At this juncture, the largest volume of orders, usually calling for products of higher standard, is likely to be forthcoming from abroad.

As for expanding available capacities, even if imports so far have to be replaced and prospects of exports are promising, it is not realistic to add new capacities at a faster rate than 5,000-20,000 tons per each stage of expansion, in view of various difficulties likely to be encountered in putting such new equipment at the scheduled time into operation, in organizing its maintainance and in providing sufficient trained personnel for handling it.

The manner of how and what raw material may be provided for to feed the facility, may greatly influence the design of the equipment and selection of technology /see sub-chapter 2.3/. If there is a smelter nearby, it is expedient for the latter to take up the manufacture of continuously-cast wide strip in addition to billets, because in doing this, costs of remelting the metal may be saved.

3.41 Principal units of operating a rolling mill

According to classical technology, the cycle of rolling is to start with hot-rolling. The minimum capacity of a hot-roll stand is about 80,000-100,000 tons in terms of finished product output. The weight of slabs to be hot-rolled is 3,000-6,000 kilogrammes, and the usual thickness of the product leaving the hot-roll stand is 6-8 millimetres.

For reasons of economy, great efforts are made to reduce final hot-roll thickness to 2.5-3.5 millimetres. With this end in view, to the above hot-roll stand nowadays a so-called semi-hot rolling stand is added, giving the workpiece a final pass before being coiled. This arrangement may permit to increase slab weight to 5,000-8,000 kilogrammes, raising the output of the finished product to 150,000 tons per year. Multi-stand /1+3 or 1+1+5/ tandem-sited hot-rolling lines may permit outputs of 200,000 and 500,000 tons, respectively.

The general width of hot-rolled strips is ranging from 1,500 to 2,000 mm.

Large reversing hot-roll stands with cylinder lengths of 3,000-5,000 mm designed to produce thick plates in the first place for the aircraft industry may not be recommended to be installed in the initial stages of establishing an aluminium industry (9).

3.412 Continuous strip-casting equipment.

This type of equipment has amply been described in sub-chapter 3.322. Its advantages may be summed up as follows:

- If installed in conjunction with a smelter, energy involved in the operations of remelting and preheating may be saved.

- Its investment costs are smaller than those of a slab casting shop and a hot-rolling mill of same capacity. Erecting semi-continuous casting units with an annual capacity of 10,000-15,000 tons each and 1,000-1,600 mm wide coils, is throughout economical.
- By now, even alloys moderately difficult to handle lend themselves well to this technology; the higher speeds of crystallization observed have certain metallurgical advantages (10), (11).
- If the trend of coping with an increasing range of specifications is going on, this may facilitate the expansion of rolling mills in stages more adapted to current demand (12).

3.413 Cold-rolling lines

Today in aluminium rolling shops almost exclusively unidirectional roll stands are installed. In case of 1,200-1,500 mm wide strip these are

- either single-stand four-high lines of 600-1,500 metre per minute rolling speed and of 30,000-60,000 tons of annual capacity depending on the thickness of their feed; coils are of 5,000-15,000 kilogramme weight each; the gauge of the end-product is 0.1-1.0 mm or
- multi-stand rolling lines /as a rule 3-5 units of four-high stands connected in series. E.g. capacity of the five-stand rolling line referred to in (15) has an annual capacity of 200,000 tons /coil weight 15,000 kilogrammes, maximum strip width 1,650 mm and smallest gauge 0.15 mm with a 1,260 metre per minute rolling speed at the last stand/.

Nowadays all roll stands of advanced design are fitted with fast-setting, flatness measuring and other control systems to compensate the elastic deformation of the stands and cylinders. In view of the fast speeds involved and the high standards of end-products sought for, manual control of the process may no longer be effective. In up-to-date designs the different, and also independently from one another functioning, controls are integrated into a central computer system. Also, each individual roll stand has to be provided with a suitable mechanism, with the aid of which any of the operating cylinders may be exchanged within five minutes.

3.414 Finishing operations.

Cold-rolled coils are thereupon subjected to different operations of finishing so as to obtain the final size and dimensions of the product as ordered by the customer. A flow sheet of such finishing operations is given in Fig.8

Transversal cutting lines are used to produce sheets of different lengths from strip. The operating speed of such a cutting line for dealing with 0.3-1.2 mm gauge sheets of 1,000-1,500 mm width and 500-3,000 mm lengths is 20-100 metres per minute. Calculating an average of product mix, its annual capacity is 20,000-30,000 tons. Its two principal components are a drum or flying shear and a stacker.

Slitting lines are designed to divide wide strips into several strips of desired width. In slitting thin strips into numerous narrower ones certain difficulties may arise in having them coiled in a suitably stretched state. Generally, by a single pass

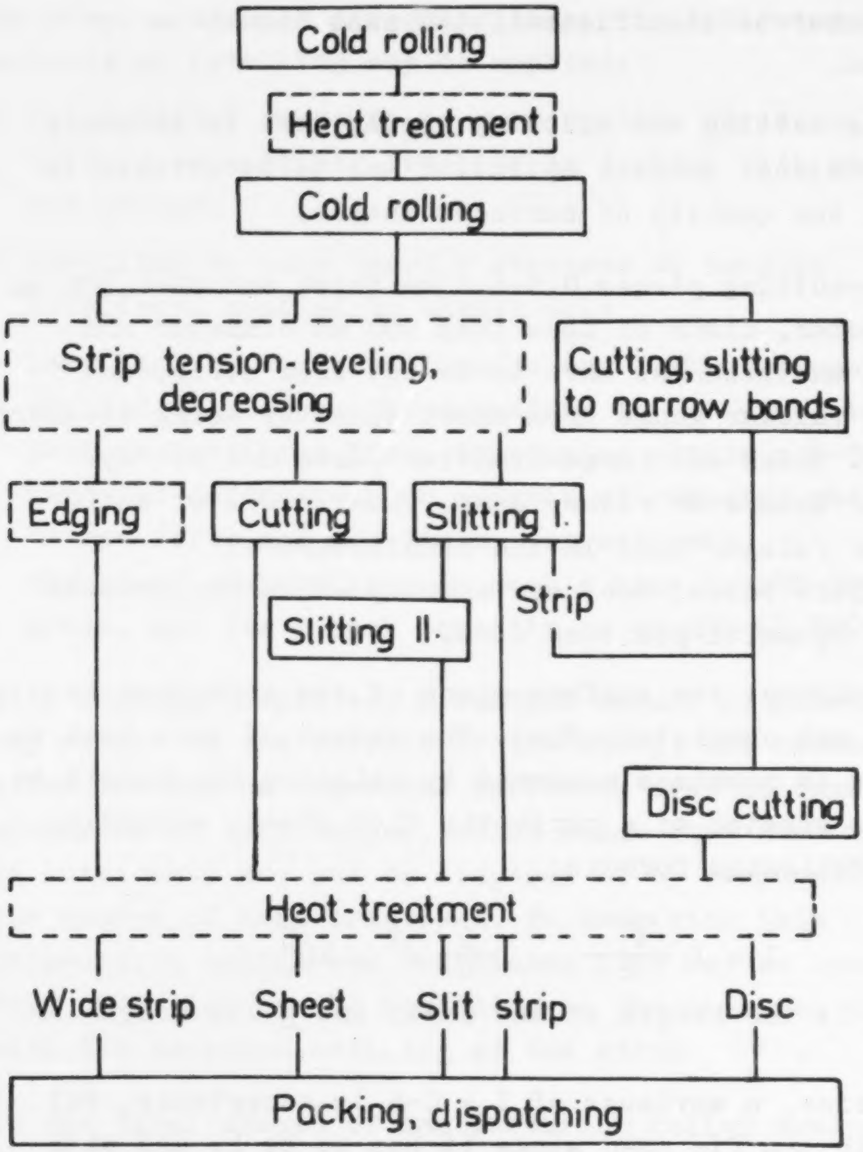


Fig.8. Finishing operations of rolled products.

ten strips of a narrower width may be produced. Should this number be insufficient, the pass has to be repeated.

In using cutting and slitting lines, next to accuracy to dimensions, special attention has to be devoted to keeping the quality of surfaces intact.

In disc-cutting pieces 0.5-6.0 mm thick and 80-1,500 mm in diameter, discs of less than 900 mm diameter and under 3 mm thickness have to be cut from strip, and such of thicker gauge from sheet bands by using excentric presses. Thick and large-diameter discs are cut by circular shears or rotary saws. Thick discs of small diameter /slugs/ used in the manufacture of collapsible tubes, too, are made by excentric presses and cut by multi-position dies.

After rolling, the surface plane of the workpiece is usually not completely flat. The extent of such bent or waviness is nowadays measured by relating its length to the same stretch of a perfectly flat sheet, according to the following formula:

$$I = / \frac{\pi}{2} \cdot \frac{h}{L} /^2 \cdot 10^5$$

where L is the length of the wave, and h its height in mm.

In practice, a waviness of I = 0-6 is acceptable, but e.g. with traffic road sings it has to be 1, and with building facade claddings 0.2. A rolled product may be considered to be flat if waves at its edges and centre are not visible by the naked eye and if it is devoid of any inner strain that may warp the product upon

further processing.
To dispose of such irregularities, the following methods of levelling may be applied:

- Intermittent exposure to pure bending stresses; this is done by a roller leveller in dealing with sheets and strips
- Levelling by pure tensile stresses on tension levellers; applied to sheets only
- Levelling by combined tensile and bending stresses applied to strips. The operation is performed by an S-block levelling line. Stretching within a 1-5% range of deformation is capable of reducing waviness to one-fifth and one-tenth, respectively.
  The speed of levelling on such a line is 150-300 m/min, and its annual capacity is 40,000-60,000 tons.

With rolling completed, a certain amount of lubricants may remain on the surface of the strip. The customer often insists on degreased surfaces, even in case of aluminium of hard temper, which means that such traces of lubricants may not be disposed of by evaporation in the course of heat-treatment. To deal with this exigency, a continuous degreasing line may be used. This operation can be combined, as the case may be, with the tension-levelling of the strip (16).

In the final stages of manufacturing rolled semi-fabricated products usually some kind of heat-treatment becomes necessary. Depending on the properties sought for, such heat-treatment may be

- Annealing; this may be a final one or performed at some point of the cold-rolling process.

- Partial annealing to obtain intermediate grades of hardness /quarter-, half- or three-quarter hard/. It may be added that such intermediate grades of hardness may also be arrived at by other methods of cold forming, e.g. by a certain amount of cold deformation by rolling after annealing.
- Tempering. This is a complex operation that may include solution heat treatment, quenching /sudden chilling by water/, dressing, and natural or artificial age-hardening.

Heat-treatment furnaces may be of a chamber type with or without using a protective atmosphere, or lines of a continuous system /to handle coils, sheets, discs, strips/ combined with a quenching chamber or tank.

Taking not a too complex product mix into account, the average energy demand of rolled products as from the slab or continuous-cast strip stage to final finish is amounting to 4.5 GJ/ton and 4.0 GJ/ton, respectively.

3.42 Some principal performance data of rolling mills.

Some important performance data by different types of rolling mills /annual production per head of labour and per suqare metre of operating area/ are given in Table 10.

Calculating 50% alloyed and 50% unalloyed semi-manufactures of 1 millimetre average thickness and 10% discs, average efficiency of output may be estimated to be about 60-70%. Allowing for such a general pattern of production, in case of items of suitable standard, a mill turnover 1.3-1.4 times the market value of the same amount of primary aluminium ingots may be arrived at.

Table 10.

Summing-up some features of rolling mills

Type of plant	Production related to labour ton/head and year	Production related to operating area tons/m^2 and year
Small and medium-size plant, wide product mix, individual rolling mills. Annual production 30,000-120,000 tons	60 - 80	0.9 - 1.5
Large rolling mill, moderate product mix, multi-stand hot-rolling line Annual production 120,000-180,000 tons	120 - 180	1.3 - 1.8
Target rolling mill, narrow product mix, tandem rolling lines. Annual production 150,000-300,000 tons	240 - 300	1.6 - 2.5

In view of the foregoing, the installation of a rolling mill in developing country may be envisaged as follows:

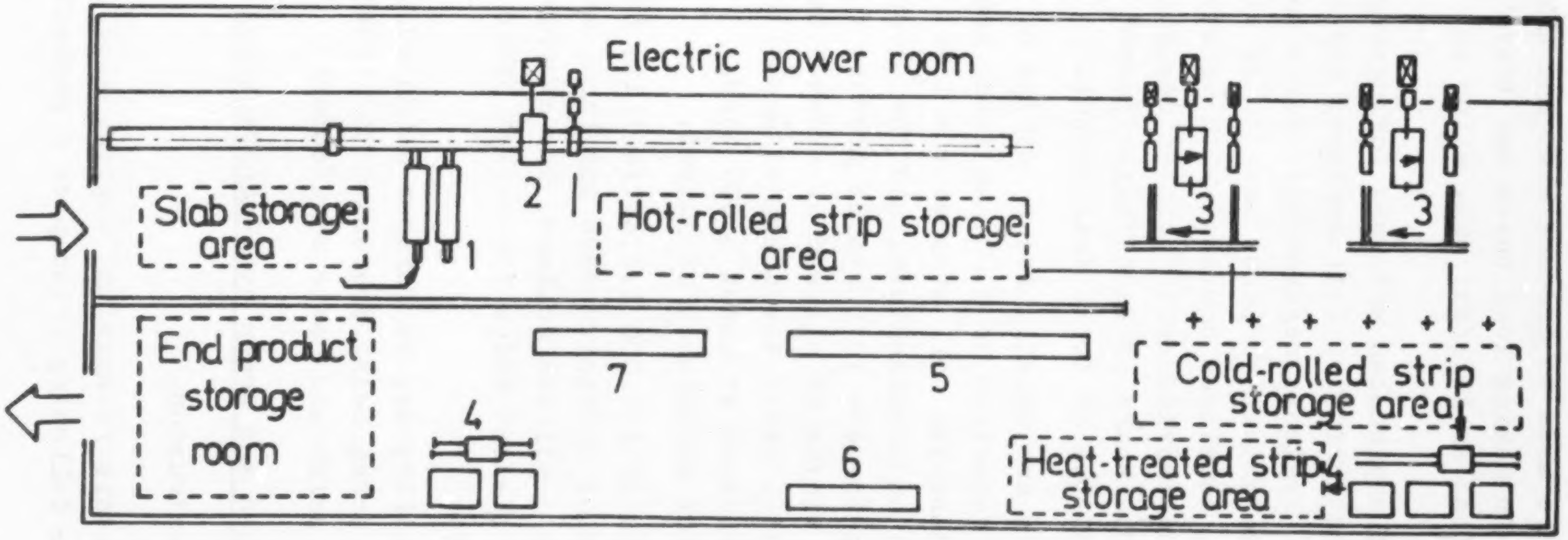
- The project would be based on the minimum feasible capacity of a cold-roll stand, i.e. 30,000 tons per year
- The cold-roll stand would have to be fed by continuously cast strip, using e.g. three Jumbo 3C continuous-casting machines
- In order to meet current demand in a flexible manner, all necessary finishing equipment would have to be installed right at the outset, even if the project were to operate in one shift only.

The cost of setting-up a 1,000 t.p.y. rolling mill capacity may be estimated to be in the order of 4 million dollars, a figure including also continuous-casting facilities, but excluding necessary infrastructure and land to locate it. Some parts of the mill may from time to time have idle capacities, a possibility rendering the project even more costly. A case in point is a rolling mill seen in Fig.9.

3.43 Foil manufacture

Foil manufacture calls for a rather complex series of operations. Essentially, it is a continuation of the normal rolling process, the salient point being the reduction of suitable strip to gauges of 0.1-0.007 mm. On commissioning the facility, the average gauge initially manufactured may be calculated at 0.020 mm.

Some 90% of metal input in foil mills is of the 1xxx group, condenser foil manufacture, however, calling for the use of 99.99% super-purity aluminium. In more recent times


Electric power room
Slab storage area
1
2
Hot-rolled strip storage area
3
3
End product storage room
7
5
4
6
Cold-rolled strip storage area
Heat-treated strip storage area
4

1. Slab preheating furnace; 2. Hot rolling mill; 3. Cold rolling mill; 4. Heat treatment furnaces; 5. Strip leveler; 6. Slitter; 7. Cutting line.

Fig.9. Layout of a rolling mill.

great efforts are made to produce AlMn and AlMg foils as well. In making foil boxes and trays for semi-prepared food an AlFe/Si/ 8011 alloy is employed.

Most of the foils produced are used for packaging. Accordingly, the purity of foil surfaces has to comply with all hygienic regulations, Foils used for decorative or technical purposes have to be airtight, often coloured, sometimes combined with plastics and/or paper and provided with printed designs and inscriptions. The share of such "high-finish" foils may amount to 30-50% of total foil output.

Foil roll stands are usually fed by strips of 0.35-0.50 mm gauge; reduction to 0.007 mm final gauge calls for at least two roll stands: the first to reduce strip to an intermediate, and the second to final gauge. Up-to-date foil stands produce foils of 1,200-1,500 mm widths at a speed of about 1,000 metres per minute. Hence the combined annual capacity of two roll stands is at least 5,000 tons, calculating a 70% efficiency of output.

Investment costs of a 1,000 t.p.a. facility proper, excluding those of infrastructure and land, may be estimated to be 3 million dollars. The average sales price of foil is about twice the market price of aluminium ingots.

Economic feasibility may be further enhanced by the resultant foil scrap being processed to pigment for utilization in paint and paste manufacture.

3.5 Production of extruded and drawn semi-manufactures.

3.51 Technology of extrusion.

Extrusion of metals /aluminium, copper, steel, etc./ is based on the following principle: a preheated or cold, usually cast billet is fed into the container of a hydraulic press: by exerting suitable pressure, the wrought metal is pushed through a die determining the shape of product thus arrived at. If one or more mandrels may be applied to enter into the opening of the die, an extruded product of one or more hollows may be obtained.

Compared to other alternatives of forming, the extrusion process has the following merits:

- Thanks to propitious circumstances of internal stresses, wrought materials lend themselves better to plastic deformation
- An almost unlimited product mix of extruded products may be manufactured, notwithstanding often strict tolerances
- Relative ease of changing over from one product manufacture to the other, permitting even smaller volumes of a given specification to be manufactured economically
- Even projects of relatively small capacities may be implemented and operated in a techno-economically feasible manner.

On the debit side, however, there are also some disadvantages:

- It is hard to keep mechanical properties called for by complying with the narrow range of permissible tolerances
- Rather small productivity of the process.

Several extrusion processes have been developed. A few of them are discussed in the following paragraphs:

- Direct extrusion. The extruded product is leaving the press in the same direction as the movement of the main cylinder exerting the pressure. Owing to its versatility, in industrial practice it is the most widely used process. The usual rated pressure of such presses is 15-35 MN, but there are also such of smaller and larger ones up to 200 MN.
- Indirect extrusion. Here the extruded product is leaving the press in an opposite direction, passing through the main hydraulic cylinder. Compared to the direct method, friction is smaller, permitting a higher rate of plastic deformation and better productivity. However, the dimensions of the products that may be extruded by this method are limited, and stringent standards as to surface quality difficult to be complied with. In the seventies it appeared that the useful properties of this method could be taken advantage of also in manufacturing shapes of soft alloys. By now, however, it has been realized that its advantages may be put to optimum use in extruding predominantly high-strength alloys of simple shape.

  Installation of an indirect press may be recommended for coping with a permanently large demand for high-strength rods, tubes and simple profiles, but only - and this is an important point - if one or more direct extrusion presses are already operating on site.
- Hydrostatic extrusion, where the deformed metal in the container is surrounded on all sides by a lubricating and pressure-transmitting fluid. Its special attraction is to produce extremely large plastic deformations at very high speeds. Therefore

its use is economical in manufacturing large series of special items, e.g. wires, plated busbars, high-strength rods and tubes. Because of the complex nature of the equipment and the high costs involved in buying it, its installation in new extrusion plants of small experience may not be recommended.

- Conform Process. Here by force of friction a mechanically driven grooved wheel is pushing through the die a coiled e.g. continuous cast rod wire. Relatively low investment costs, ease of switching over from one type of product to another, and small amount of energy involved in its operation are the principal reasons why this technology is steadily gaining ground in the manufacture of extruded products of small dimensions. It certainly does not replace direct extrusion, but may be used with advantage as an additional method by a plant just starting operations and called upon to turn out extruded products of small size as well.

There are a number of other innovative extrusion processes too, but these are at this juncture yet at an experimental stage. Cases in point are technologies featuring active friction (18) , the use of multi-opening containers (19) and some types of continuous or semi-continuous extrusion (20) , not discussed above, etc.

Drawing as a technology has already been known and practised in the Middle Ages. Today equipment used for such ends is of a great variety, from chain-operated simple drawbenches to multi-wire or coil fed automatic production lines, wire-drawing machines operating in several successive stages with or without friction, etc.

Notwithstanding the multiplicity of equipment discussed above, wherever alternative projects for developing countries are dealt with and referred to as "extrusion" in this study, it is always direct extrusion that is meant.

Apart from some extreme cases, aluminium alloys have to be extruded in the hot state. The cast billet /see 3.321/ has to be homogenized so that it may lend itself well to plastic deformation. Preheated to suitable temperature /depending on the alloy, the type of its final temper and mechanical properties/ and cut to optimal length, such homogenized billets are thereupon to be extruded at fixed speed, varying with each alloy. In determining the magnitude of speed, the total percentage of alloying constituents has to be taken into account; the higher it is, the slower has extruding to be. Other factors, too, affect extrusion speed: the complexity of the item to be extruded, and the design of the die. Thus, whilst a non-alloyed wire may be extruded at the speed of several hundred metres per minute, the corresponding figure for high-strength sections made from 2xxx or 7xxx alloys may only be a few metres per minute or even less.

Extrusion speeds may be increased and both the surface and mechanical properties of the products improved if the billets from which they are made are first homogenized and then cooled in an optimum manner. Controlled cooling after homogenization is especially important when the process of quenching is to take place at the press.

The surface of products may further be improved if the region at the exit side of the die is pervaded by gaseous nitrogen. When the liquid nitrogen is evaporated in the die itself, cooling of the die permits a further increase of extrusion speed. Doing this, however, calls for a high degree of automation and great technical skill (22).

In case of low- or medium-strength age-hardenable alloys, the solution heat-treatment and quenching necessary to enhance mechanical strength are done jointly with the process of extruding. This technology is considerably reducing production costs of such items, for the costs of using a separate furnace and energy necessary for reheating the product may be saved. In case of quenching at the press thinner-walled shapes from low-strength alloys such as AA 6063, air-cooling by fan may suffice; as for midle-strength alloys, e.g. AA 6005 or 7020, or for items of stronger walls, water-sprinkling has to be applied, whereas for alloys of even greater strength quenching of the extruded strand by passing in through a water tank may not be dispensed with.

When a product is quenched next to the extrusion, to reduce production costs and to protect surfaces, stretch-dressing and cutting of the product is taking place at a finishing line integrated into the extrusion press.

At the end of the line the products are collected in pallets, to be age-hardened subsequently. After it, the product is either dispatched to the customer or kept by the semi-manufacturer for further processing, should he himself have facilities to produce finished items.

If in quenching age-hardenable alloys such fast cooling speeds are called for as may not be arrived at the press

/e.g. in case of AA 2024 or 7075/, solution heat treatment and quenching have to be performed in a separate furnace.

Should a non age-hardenable product be manufactured e.g. from a 5xxx alloy, the required mechanical strength has to be arrived at by subsequent cold-forming of the extrusions, in most cases by drawing. Drawing will also be necessary when such stringent tolerances are called for that these may no longer be complied with by extrusion alone or by any other hot-forming process.

From a raw material and technological point of view, prerequisites governing the manufacture of viable extruded semi-fabricated products may now be briefly summed up as follows:

- Billets of a suitable metallurgical structure, surface and geometric shape; their optimum homogenization coupled with controlled rates of cooling
- Extrusion dies of proper design, ensuring the desired dimensions, tolerances, surfaces and distortion-free shapes of products to be manufactured at prescribed speeds
- Strict compliance with manufacturing parameters
- Effective protection of surfaces from damage during the finishing operations and materials handling

By installing a new plant or updating an old one all manufacturing equipment has so to be chosen as to meet the above demands.

3.52 Principal equipment of an extrusion plant /including drawing/.

Whether a project for an extrusion plant is to be implemented in a developed or developing country, its future operator has to be fully familiar with the type of equipment that is most likely to render him competitive on the market with products which are not only up to suitable technological standard but also turned out by him in a commercially feasible manner. Such a new or modernized plant has to be equipped with up-to-date facilities.

A description of all operating equipment in technological sequence is given below.

3.521 Preheating, cutting to measure and homogenization of billets.

Preheating of billets before extrusion may be made either in gas- or oil-fired or induction-heated continuous furnaces. Until recently, preference was given to the use of gas-fired furnaces, not only because costs of their purchase, installation and operation are favourable, but also because they may permit the preheating of logs and their subsequent cutting in a hot state. Lately, however, the cost gap between gas-fired and induction-heated furnaces has narrowed. Thus, as in a not too distant future the problem of preheating billet logs in induction furnaces too will be resolved (21), the situation as to what type of furnace may be used with optimum advantage, will have to be revised.

Hot-cutting of low and medium-strength alloyed billets poses no problem; high-strength ones, however, have to be cold-sawn prior to preheating. If the cutting of billets is done beside the press and is done in an organized manner, scrap arisings may be reduced by 5-6%, and the press may operate with utmost efficiency, favourably affecting production costs.

Preheating furnaces have to be automated at least so as to keep prescribed temperatures.

Specific energy consumption of modern billet-preheating furnaces is approximately as follows:

Gas-firing: 0.75-0.9 GJ/t + 5-7 kWh/ton
Oil-firing: 0.80-0.95 GJ/ton
/In both cases using recuperators/
Induction furnaces: 250-300 kWh/ton.

In most up-to-date plants homogenization of billets is combined with the operation of preheating. The logs are first heated to homogenization temperature, then kept in a holding chamber, and thereafter cut and water-cooled to extrusion temperature. By this technology energy may be saved, extruding speed may be increased and high-quality extruded products may be obtained.

3.522 Extrusion

At first sight, modern extrusion presses look similar to their older counterparts, with their main components remaining unchanged. However, the former accumulator water-emulsion hydraulic drive is replaced by individually driven pumps. In order to permit easier access, these are located beside the press on the floor, or with a view to reducing noise level, in separate premises. The rigidity of the presses are now eased by prestressing, and their uniaxiality is improved by so-called X-guiding. The latter is needed for using fixed dummy blocks.

What is most striking in new presses, is the way of how they are being controlled. Mechanically operated terminal position switches difficult to set and sometimes of questionable accuracy, slow servo valves and some other components have by now been replaced by electronic remote controls, which - based on microprocessors - are reliably programmable (23) .

As from the early eighties, new extrusion presses are furnished with PC /programmable control/ or PLC /where "L" stands for "logic"/, all embodying a microprocessing control system. Meanwhile, too, efforts are made to have also presses of older design modernized so as to reduce production costs (24) .

Calculated for a 5-day working week and three-shift operations, the annual output of presses per unit of pressure force is roughly as follows:

190-320 t/MN in case of average commercial specifications, and
150-200 t/MN when a large percentage of production may be accounted for also by more complex alloys /mostly medium- and high-strength tubes and high-strength rods/.

3.523 Finishing within the extrusion line

Principal finishing equipment integrated with the press into an extrusion line are as follows: fixed table with built-in water tank, 40-50 metre long runout table with puller, walking-beam cooling table and/or transverse conveyor system, stretcher, cutting-saw with rollers, and as an optional extra, a stacker. The puller is designed to lead the discharge end of the extrusion so as to ensure the required stress. To protect product surfaces, all equipment in contact with them are given a graphite or heatproof plastic lining to prevent them from sliding sideways. The saw is fitted with a suction exhaustor to remove chippings. How far the line is automated may vary from partial automation /e.g. automatic lifting of the extrusion from the runout table/ to fully automated and computer-controlled systems. There exist also - so far very costly - automatic stackers (23) . This work, however, may also be easily done manually, in combination with quality control.

3.524 Finishing operations outside the extrusion line, cold-working and heat-treatment.

The finishing of all high-strength and also part of medium-strength products, as well as that of drawn workpieces, has to be done separately. For this purpose, stretcher and roller machine, excentric and hydraulic presses are used. For cutting, usually disc saws are used. Drawing machines have already been referred to under an earlier sub-chapter. For age-hardening /low-temperature heat-treatment/ of products quenched at the press, continuous aging furnaces forming an integral part of the extrusion press line already exist. However, in most extrusion plants conventional chamber-type gas-fired or electric resistance-heated furnaces are in use. A special feature of solution heat-treatment furnaces is their upright design with a water tank underneath, into which, so as to reduce risks of warping, the extrusions are fed vertically to be quenched. Capacities of such units are varying, but their output is rather on the modest side, i.e. 1,500-3,000 tons per year.

3.53 Establishment of an extrusion plant.

The smallest technologically still feasible extrusion plant has one extrusion press. However, unless it is working in three shifts, its operation may not be economical. Type and capacity of the press to be installed should rather be governed by the product mix then by the envisaged production volumes. Of course, a too small press would hardly be able to manufacture a suitably large range of products and would thereby weaken the future market position of its operator /e.g. the transport vehicle industry is almost exclusively using large extruded sections/. It would, further, prevent him from producing sufficiently large volumes of medium- and high-strength items as well. On the other hand, if too large a press were to be installed, it would leave him stranded, with some of its capacities remaning idle, a fact considerably increasing production costs.
Moreover, prior to launching a project for a new extrusion plant or for streamlining an available facility, it has to be decided whether and how far equipment has to be automated.

Obviously, a fully automated "no man" extrusion plant would hardly be welcome in a developing country at the outset. However, it should not be overlooked that probably in 5-10 years this may be the only feasible alternative. Although in developed countries the main motivation for automation is savings in costly manpower, the technological merits of automation should not be underrated: significant improvements in product quality, elimination of human failings and errors, better utilization of achievements by advanced science, reduction of scrap and reject, more effective use of available equipment and higher productivity. Such and similar problems have to be coped with even today by a great number of operators in developed countries.

However, even if sufficient financial means for full or partical automation were not available /e.g. an automated finishing line excluding press and stacker costs 200,000-250,000 dollars more than a conventional one/, on purchasing basic equipment, the ultimate envisaged standard of technical development has to be taken into account, along with all successive stages in which this final goal may be implemented. Accordingly, all basic equipment has to be of such design as to be adaptable to automation and more advanced forms of operations in the times ahead. In this respect e.g. slow servo units may be a great hindrance of electronic control (19), (23), (24).

For further details as to how an extrusion plant combined with drawing facilities may best be set up, the reader is referred to another UNIDO study published in 1984. (21) The concept underlying this study calls for a stepwise addition of new capacities as demonstrated by Fig.10.

Here the technical development process is starting with the establishment of a single-press extrusion plant. It is designed in the first place /80-90%/ to produce sections from highly extrudable alloys and smaller volumes of medium-strength structural items to be mainly used by the building trade. Its production programme may also include the manufacture of some non-alloyed or low-strength tubes and wires as well. The installation of this single-press facility /Fig.10/a/, as well as of

Fig. 10. Layout of equipment in an extrusion plant [21]

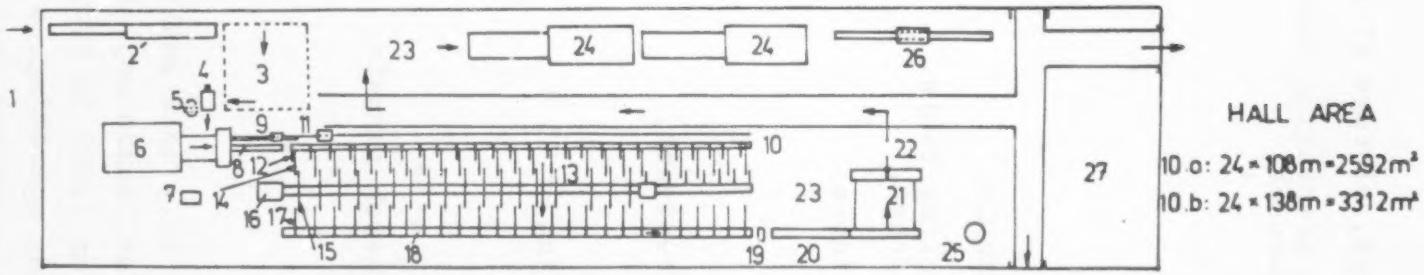


Fig 10.a Press line and attached facilities for manufacturing profiles of highly extrudable alloys.

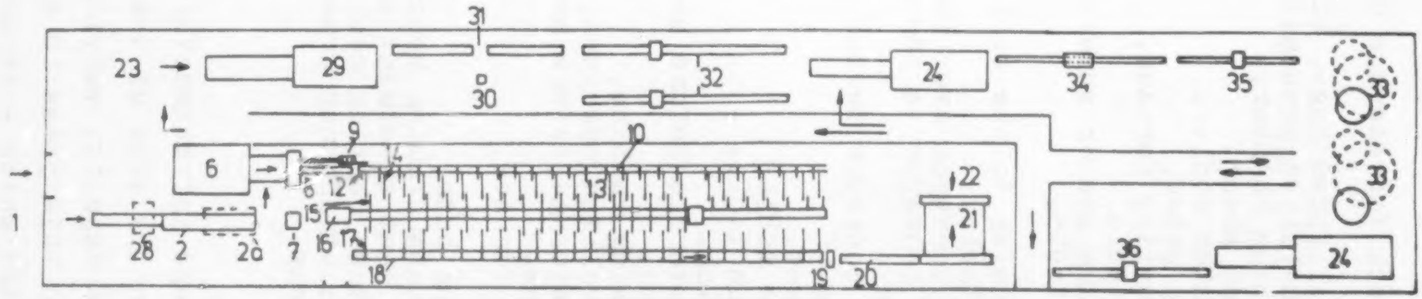


Fig.10.b Tube and rod press line and attached facilities for extruding products of high strength alloys.

Fig.10

1 - Sloped rack for storage of logs, storage of logs and billets,
2 - Gas or oil fired log-, billet preheating furnace,
2a - Induction billet preheating furnace,
3 - Homogenizing chamber,
4 - Hot billet shear,
5 - Billet water cooler,
6 - Extrusion press,
7 - Die preheating furnace,
8 - Initial table,
9 - Hot cutting saw or shear,
10 - Run-out table,
11 - Puller,
12 - Lift transfer to the cooling table,
13 - Cooling table,
14 - Transfer conveyor over the cooling table,
15 - Transfer conveyor to the stretcher,
16 - Stretcher,
17 - Transfer conveyor to the saw table,
18 - Saw table,
19 - Cutting saw,
20 - Saw gauge table,
21 - Inspection table,
22 - Palletizing,
23 - Product storage before heat treatment,
24 - Aging oven,
25 - Wire drawing machine,
26 - Profile rolling machines,
27 - Product storage before anodizing,
28 - Billet saw,
29 - Anealing furnace,
30 - Hammer,
31 - Degreasing bath,
32 - Rod and tube drawing benches,
33 - Solution heat treatment and quench furnace,
34 - Rod and tube rolling machine,
35 - Hydraulic straighner press,
36 - Cutting saw.

its building and infrastructure is only to a small extent dependent upon the size of the press, which may thus be designed for a capacity varying from 4,000 to 8,000 tons per year. When this press is already operating, a second one may be added which - depending on market conditions -

may be a profile press of same type, but larger if demand for the original specifications and somewhat more sizable items should be increasing. However, if the manufacture of alloyed tubes, too, is envisaged, the choice will have to be a tube /universal/ press /Fig.10/b/. In this event the extrusion plant - along with its drawing and heat-treating facilities - will be capable of manufacturing a very wide range of products /40-50% highly extrudable items, 30-40% medium-strength- and 20-30% high-strength alloys/. The annual capacity of this two-press plant /Figs. 10/a and 10/b/ would vary from 9,000 tons to 13,000 tons. What is really important is the effective and quick implementation of the project so as to ensure a fast rate of capital return.

Generally speaking, in implementing an extrusion plant project several prerequisites have to be complied with. Cases in point are e.g. a suitable infrastructure and competence of engineering personnel /see sub-chapter 3.10/. Another important point is the availability of the necessary extrusion dies. No extrusion and drawing plant may go on operating without quickly obtainable high-quality dies. According to experience, even in the presence of an excellent industrial background, no extrusion plant may solely rely on dies to be furnished by outside sources, but has to set up a workshop of its own to manufacture at least some of the dies locally.

Furthermore, no extrusion plant project may be successful unless backed by a sufficiently large and responsive market. It may only operate effectively if the product mix turned out by the plant is in agreement with what the end-user is capable of further processing. Should in the closer region be no sufficiently experienced consumer /e.g. a manufacturer of transport vehicles or building components/ the extrusion plant may be called upon to furnish items processed to such finish that all the customer would have to do is to assemble them by some mechanical means or, as the case may be, just manually. Of course, the more developed the end-using industries are and the higher the standards that are called for by the export markets, the more hard-pressed the works will be to turn out large volumes of high-quality products.

As far as drawing in concerned, the minimum capacities involved are small. In actual fact, a workshop with a single simple drawing bench may suffice. /See e,g. item 32 or 25 in Fig.10./ The smaller a plant, the more important is the installation of simple drawing machines. Automatic machines are normally high-duty ones calling for the manufacture of large series to be supplied to more demanding markets. An independent drawing plant has to be continously fed with stocks of material by a relatively nearby extrusion plant. If the latter is willing to cooperate and has sufficient heat-treating capacities, the drawing plant should be furnished with drawbenches as well as with pointing and cutting equipment only /see items 30, 32 and 36 of Fig.10/. In the absence of such cooperation as outlined above, the installation of a heat-treating - in the first place annealing - furnace may not be dispensed with /item 29 of Fig.10/. Similar equipment is also necessary when an extrusion plant is to operate drawing facilities of its own.

3.6 Manufacture of rod wire and drawn wire.

In developing countries a large percentage, as a rule 30-50% of total aluminium consumption, is devoted to the manufacture of electrical conductors. Therefore it is necessary to dwell at some length on different alternatives of producing rod wire from which, in turn, electrical conductor wire is made.

The major part of such electrical conductors is used for transmitting electric energy in 750-66 kV high power and 66-1 kV medium-power outdoor grids, as well as in low-power outdoor systems under 1 kV. Such outdoor conductors, usually uninsulated but in some cases insulated, are stranded from 2-4 mm dia. wire made from electrical-grade 99.5% aluminium or AlMgSi alloy. In case of high and medium-voltage overhead conductors, mostly steel-reinforced stranded aluminium cables are used.

In contrast to normal non-conductor wire, the one used in electric power transmission has to meet a number of most stringent demands as to highest electric conductivity and tensile strength, toughness and creep-resistance. Therefore throughout the world such conductors have to be made either from a 1350 A material as ruled by AA standard specifications or from an EAl 99.5% material according to DIN. /For more details refer to 4.3 sub-chapter/. In medium-voltage outdoor conductors the use of the EAlMgSi alloy as per DIN is steadily gaining ground owing to its higher tensile strength and easier technique of installation.

Next to stranded outdoor conductors and insulated overhead cables, another significant outlet of aluminium is the use of round insulated power distributing cables. Up to 1 kV they are made from solid angled-section EAl 99.5% wires. Beyond this voltage, it is still open for controversy whether cables of stranded or solid wires or such with angled sections be used. /For more details refer to (1)/.

3.61 Rod wire manufacture by continuous casting.

According to estimates, 90-95% of rod wire from which electrical conductors are made is manufactured by continuous casting and wound into coils of 1-3 ton weight each. Most of them are manufactured in the casting shops of smelters. The material from which continuously-cast rod wire for electrical ends is made is a special boron-treated, purified and as to composition carefully checked grade of aluminium. After repeated treatment /see sub-chapter 3.3/ the metal is fed into a water-cooled wheel, an essential part of the equipment, acting as a continuous mould in preparing continuous-cast skeins. The latter is passed on for further operation to a stand with 10-16 cooled-lubricated and suitably calibrated pairs of rolls. The resultant 8-16 mm dia. rod wire is thereupon wound into twin-coils. It is desirable to provide sufficient space between the roll line and the site where coiling is to take place, an arrangement permitting the setting of the exact temperature of the finished wire by the installation of an effective heating and cooling system. The capacity of a continuous-casting equipment for non-alloyed electrical-grade aluminium may vary from 1 ton to 12 tons per hour. Rated capacities for alloyed aluminium are 15-25% smaller. Today, usually units of 20,000-30,000 ton annual capacities are used. Their purchase and installation costs per 1,000 ton annual capacity, without building, may amount to 170,000 dollars each, including winder, two tipping twin-furnaces for casting and a continuous purifier. For a layout-scheme refer to Fig.2. At a separate workshop near or distant from the smelter non-alloyed aluminium rod wire coils are reduced in gauge by fast drawing machines. For stranding such drawn wire separate stranding machines are used. It is useful to have a continuous wire-annealing furnace located close to the drawing and stranding machines.

The continuous-casting of section wire is only economical in case of very large series because of the high costs of rolls and loss of time involved in exchanging them. For reasons of accuracy-to-dimensions, and in order to obtain smooth surfaces, it is necessary to subject section wires to subsequent calibration by a single operation of slight drawing.

Continuous-casting machines are manufactured by various specialized engineering firms. The names of some are given in chapter 3.10.

3.62 Rod wire manufacture by extrusion

With continuous-casting almost universally adopted, only in exceptional cases is electrical-grade rod wire produced by extrusion. Cases in point are the manufacture of section wire and - if sufficient idle extrusion capacities are available - 8-16 mm dia. rod wire. In both cases it is absolutely necessary that in view of the large /e.g. 1 ton/ coils obtained by billet-to-billet feeding of the press, the container of the latter should lend itself well to evacuation, and that for coiling the runout wire twin-winders of sufficient capacities be available. In 1960-1970 this technology was practised by the British Insulated Cable Company /BIIC/, and this is how the Székesfehérvár semi-fabricating plant of the Hungarian Aluminium Corporation is even today manufacturing in the first place section wire. For continuous extrusion of conductor-grade wires even obsolete types of extrusion presses may be used with advantage if adapted to such technology; this, however, is calling for sufficient skill and experience. Such know-how is obtainable from Hungalu Engineering and Development Centre of Hungary.

Production costs of extruded rod wire are always higher than those of their continuously-cast counterpart. Thus, the price of continuously-cast rod wire coils made from EAl 99,5 aluminium in 1984 in Hungary was 1.14-times that of aluminium ingots, whilst the corresponding figure for extruded rod wire was 1.17, the difference being 15%. However, in manufacturing section wire, extrusion is always more economical, especially if the standard of surfaces has to be high.

3.7 Manufacture of forged products.

The forging of aluminium made great headway in the 1930s when new aircraft industries came into being. In more recent times this process has found wide acceptance in the wake of rising energy prices, especially in the transport vehicle industries producing trucks and passenger cars /e.g. wheel suspensions, pedals, shock absorbers as well as brake and buffer members/. Next to cast ones, nowadays also forged pistons are being widely used. In numerous machines and appliances, too, forged aluminium components may be found, especially small-size ones, e.g. in laboratories high-strength specimen-holder heads for centrifugues. Also in electrical engineering, owing to the good conductivity and mechanical strength of aluminium, various items such as clamps and joints are made by forging the metal. Practically, in every sector of industry some forged pieces are used in more or less small volumes. Further outlets include links of fire-hoses, fittings of aluminium pit-props, necks of aluminium liquid gas bottles, etc. As for demand in forged pieces, it should be emphasized that

- their major users are developed industries, therefore a forging shop should only be installed in areas where a sufficiently high-standard industrial background may be found, and
- in view of the fact that such forged pieces have as a rule to cope with strong and in most cases dynamic stresses, not only stringent tolerances are called for, but also special consideration has to be given to the design of the die, the manner of metal-flow in the process of forming, the structure and mechanical strength of the forged product in all directions, and as to whether any residual strains have remained after completing the operation of forging.

To sum up, the installation of an aluminium forging shop may not be recommended to a plant that has but little experience in the technology of forming.

Another important point is how and in what form to obtain material to feed such a facility. Usually such a material is an extruded and only seldom a cast one.

If in the area a sufficiently developed industrial background exists and market prospects for selling such items are fair, next to an already established extrusion plant the addition of an economically operating forging shop is throughout possible. An advantage of such a project is that it may be started in a small way and expanded later step by step.

Forged pieces are almost exclusively manufactured by die-forging, a technology calling for a great deal of accuracy in forming. In each case, shape and dimensions of a semi-fabricated forged piece have to approximate as much as possible those of the finished product, so that prior to be used, further processing by the customer may be eliminated or reduced to a reasonable minimum.

3.71 Principal equipment and operations of forging.

- Cutting the workpiece to be used; for this purpose usually fast circular disc-saws are used; accuracy of feed is of utmost importance /0.05-0.1 mm/;
- Before forging, the workpiece has to be preheated in a gas- or oil-fired or electric resistance furnace, which in most cases is a continuous one; die-preheating is as a rule done in electric-resistance-heated ovens;
- The presses are usually of energy type with direct electric or friction drive and of various ratings /as a rule 2-15 MN/. In up-to-date machines the feeding of energy is electronically

controlled, permitting optimum parameters of forging and utmost protection of both machine and dies;

- The trimming of forged pieces is usually done by excentric cam presses;
- For heat-treatment, conventional small-capacity /e.g. 1-ton/ electric resistance-heated furnaces are employed.

Investment costs of a forging shop are fairly high: for 1,000-ton annual capacity using cast and/or extruded feedstock they may amount to 8 million dollars to start with. On the credit side, however, is the favourable pricing of forged products. Calculating an average weight of 0.3-kilogramme per piece made from a medium-strength alloy, the market price is 2.5-times that of an aluminium ingot. For operating a 1,000-ton per year facility, a workforce of 30 is required.

3.8 Operations of higher finish.

In comparison with competing materials, aluminium has numerous advantages: it lends itself well to plastic deformation, its mechanical strength per unit of weight or volume is good, its corrosion-resistance and electrical conductivity are excellent, it is non-toxic, etc. Most of these properties apply also to aluminium in the alloyed state. In absolute terms, however, this is not always true. It would hardly be correct to say that the mechanical strength of non-alloyed aluminium is high, that alloys 2024 and 7075 are easy to form or were corrosion-resistant, that it would be right to use aluminium outdoors without some previous surface-treatment, or to start manufacturing food cans from strip without an inside resin-coating, etc. No doubt, aluminium has an attractive surface at the outset; however, when not properly treated, owing to its relative softness it may soon become defective, grey and susceptible to corrosion. Hence, to protect aluminium surfaces, an effective surface-treatment has to be applied.

Several such processes have been developed and are sometimes also practised by independent firms specializing in such work /see sub-chapter 2.31/. However, there is nowadays a growing trend throughout the world that semi-fabricated products be surface-treated right at the plant where they are manufactured. There are several reasons for this. On one hand, a semi-fabricating plant is obviously striving for higher profits to be derived from a product wherein operations of higher finish, too, are already embodied. But on the other hand, it is also in the interest of the buyer to have such finishing operations performed by the semi-manufacturer himself, for with the exception of major consumers, most of them are not in a position to run e.g. an anodization line of cost-effective capacity.

The most frequent processes of surface-treatment are

- coil-coating /lacquering/,
- anodizing, and
- painting.

Rolled strips may be further processed by the semi-manufacturer to

- profiles by plying, or
- welded tubes.

Another trend for producing items of higher finish at a semi-fabricating plant aims to be of greater service to the customer on one hand, and to sell products of higher intrinsic value, on the other hand. With this end in view, several items of higher finish have been developed such as

- patterned, expanded, and perforated rolled products;
- for various purposes complete "packages" of items ready for assembly;

3.81 Coil-coating of rolled products.

Coated sheets and strips of various colours are in the first place used for cladding buildings and the bodywork of transport vehicles. Fair volumes may also be employed in renovating facades of old buildings as well.

Coil-coating is done by continuous production lines using wide strips. The minimum annual capacity of such a line is 5,000-10,000 tons. There are also narrow and extra-narrow strip coil-coating lines by which, amongst others, also venetian blinds to be mounted on windows to screen off sunshine, are made. In developing countries the installation of latter lines may be of special interest because

- most of such countries are located in regions of hot climate where the use of venetian blinds may render air-conditioning more effective and permit thereby savings in energy;
- the capacities involved are on the modest side /600-700 tons per year/, calling for small capital investment, and

- equipment to coat strips for venetian blinds is easy to install either at the customer's premises or at a semi-fabricating plant.

In turning out various packaging items for the food industry including non-drink, and drink cans, usually a 0.15-0.30 mm gauge strip is used passing through a wide-strip coil-coating line. Here the minimum economically feasible annual capacity is about 5,000-10,000 tons. For coil-coating aluminium, with slight alterations, also conventional heat-treating lines as used in tinplate manufacture may be employed. After every operation of surface finish the sheet or strip remains pliable, and in case of coated strip for the food industry even deep-drawable without harm to the lacquered surfaces.

The main components of a coil-coating line consist of an unwinder, surface treating member /for purifying the surface and producing a basic oxide film/, a lacquer dispenser, lacquer-fusing furnace, cooler and winder. In installing a coil-coating line, particular attention has to be devoted to the proper storage of lacquer and the locating of preliminary operations, as well as to safeguards against environmental pollution. The basic materials of lacquer are usually inflammable organic solvents, and both the solutions and diluted liquors are hazards to human health and the environment.

3.82 Anodization of extruded and rolled products.

For a long time, there has been no alternative to surface-treating extruded products but anodization. In recent times, however, the painting of aluminium surfaces is becoming increasingly widespread.

Rolled products are anodized in sheet form mainly to serve as decorative claddings to be used by the building trade. Prior to the process of anodization proper, surfaces have sometimes to undergo certain preliminary mechanical treatment /abrasion, brushing, polishing/ performed by different target equipment. This work is rather time-consuming and performed only when a highly decorative effect is sought for. Normally, developing countries need not install such equipment. On the other hand, all chemical and, as the case may be, electrochemical operations of surface treatment /e.g. satining, pickling/ have to be integrated in the anodization line. Of the various anodization processes nowadays used, colourless anodization by D.C. producing a surface film of natural lustre, and its electrolytic colouring by using inorganic salts are the most widespread. After anodization and dying, the resultant oxide film has to be sealed.

An anodization line is made up from tanks wherein chemical solutions /electrolytes/ of strictly controlled composition or sprinkling water are kept. The line is provided with both D.C. and A.C. power. The items to be anodized are fixed onto frames and dispatched from tank to tank by automatically programmed crane, while a special micro-processor system is keeping all necessary parameters under control. Automation is important in ensuring a uniformly high surface quality; programming, moreover, is facilitating the changeover from one technology to the other. In anodization lines of advanced design energy savings may amount to 50% compared with obsolete, manually controlled lines. However, in developing countries where sufficient funds may not be available, at the outset the installation of manually controlled anodization lines may still be an acceptable alternative.

To treat items of an average specific surface, the smallest optimum annual capacities are 2,000-4,500 tons for profiles, and half of this figure for sheets. Of course, there are also numerous anodization plants of several times that capacity, but such projects are realized by multiplication of optimum lines. Total investment costs of a complete profile anodization line of 3,000-6,000 tons annual capacities, including building, power supply and sewage treatment is to be found in another UNIDO study listed under the References (21) . Simpler and smaller capacity anodizing equipment than the one mentioed above, may also be installed. While in such cases capital investment involved is smaller, specific labour costs are rising and the standard of anodized surfaces may be inferior. Establishment of such a facility may only be recommended for anodizing mass-produced items of smaller size.

3.83 Profile painting.

Originally launched in Europe, this breakthrough in surface-treating technologies has meanwhile made considerable headway in America as well. In quality, painted surfaces are often almost as good as anodized ones, permitting an increased variety of colours. The application of dry technologies /the use of powder paints/ has several marked advantages as summed up below:

- no harmful residues polluting the environment;
- easy change from one colour to the other;
- almost 100% utilization of paint input, and
- in many cases low prices of the paint.

Some firms are operating both anodization and painting lines side by side.

3.84 Strip-profiling lines.

Under this technology profiles of relatively simple design are manufactured in such small wall-thicknesses and/or large widths as no other process is capable of doing.

The material fed into the production line is usually coil-coated or less frequently just not treated strip. From wide strip, trapezoidally or sinus-wave corrugated strips or sheets are made for the cladding of buildings and the bodywork of transport vehicles, while such made from narrow strip /400-500 mm/ are used in manufacturing suspended ceilings. This technology, however, has also some drawbacks: the relatively large annual capacities involved in rendering such a project a paying proposition /10,000 tons for wide and 1,000-3,000 tons for narrow strip/, the high costs of operating equipment and instrument /series of grooved rolls/. There are also production lines of smaller capacities, using sheets. Anyway, it is expedient to be prepared for manufacturing a wide selection of items, although in such case some equipment will be operating at 20-25% capacity only.

3.85 Welded tubes from strip.

Advantages and disadvantages are similar to the ones above. The matter, however, is complicated by the fact that in this case several production lines of machinery are needed to turn out a wide selection of tubes. Welded tubes are used in manufacturing camping furniture, aerials of small-diameter, and agricultural irrigation systems with large-diameter tubes.

3.86 Patterned, expanded and perforated items.

By this technology patterns of varied design are applied onto the surface of usually thick plates by cold-rolling. These items are used as claddings, floors, etc. Patterned cylinders are rather expensive to make and should only be purchased from specialists. To meet a multiplicity of demand, a sufficiently large number of such cylinders have to be kept in readiness. If a semi-manufacturer has only one rolling-mill stand, taking-up the manufacture of such items may not be recommended. On the other hand, patterned plates may also be produced by an old rolling-mill.

In manufacturing fences and some room dividers expanded sheets are used by cutting up and expanding such sheets according to a given pattern.

Perforated sheets are punched by special automatic target machines. They are used e.g. in manufacturing suspended ceilings.

3.87 "Packages", a combination of ready-for-assembly items for specific purposes.

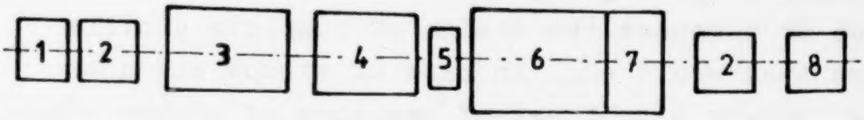
This method has been devised in the first place for using a variety of extruded products in regions where the standard of industrial services is low. Such "packages" may be used with advantage in assembling e.g. windows, doors, shelves or modules of furniture on site, with some skill even manually.

In designing "packages", the semi-manufacturer has to develop or purchase the design of complete profile systems that would e.g. in case of window and door frames include a full set of sections of proper shape, dimensions and finish, corner members, screws, fittings and insulations, all ready for assembly forthwith. Before developing or buying such systems, however, the semi-manufacturer is well-advised to approach first any of the major aluminium consulting bodies outlined in sub-chapter 3.10.

3.88 Installation of production lines for manufacturing items of higher finish.

Strip coil coating, tube-welding, strip-profiling etc. lines may be installed either at the semi-fabricating plant itself or at another location elsewhere. In the latter case, of course, provisions have to be made for the continuous supply of strip. Depending on market demand, such projects may be implemented in successive stages. Notwithstanding the multiplicity, design, size, capacity and range of items to be produced, a general layout-scheme of them is given in Fig.11 followed by a rough estimate as to investment costs involved in such ventures.

The areas given in Fig.11 refer only to location of the manufacturing line proper. It has to be increased by space necessary for the storage and transport of feedstuff and finished product. As a rule of the thumb it should be accepted that the manufacturing line should not take up more space than that of 40-50% of the total premises. In addition, extra space has to be provided for packaging and the separate storage of auxiliaries /lacquers and sundry chemicals/.



Area required for the line:

Fig. 11.a. Wide strip coil-coating line 800m²

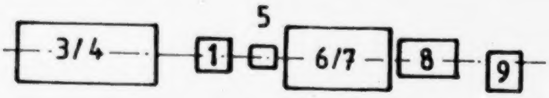


Fig. 11.b. Narrow strip coil-coating line 150m²

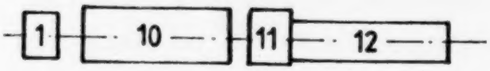


Fig 11.c. Narrow strip profiling line 150m²

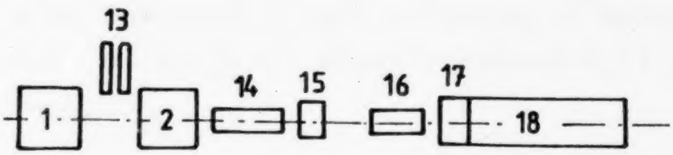


Fig. 11.d. Tube welding line 350m²

Fig. 11. Examples of manufacturing and/or finishing some special semifabricated products

Fig.11

1. De-winder
2. Strip accumulator
3. Purifier, degreaser
4. Preliminary surface treatment and anodization
5. Application of lacquer
6. Lacquer fusing
7. Cooler
8. Winder, lifter
9. Embosser
10. Profile rolling line
11. Saw
12. Finishing table
13. Manual welding apparatus, splicer
14. Tube rolling stand
15. Welding equipment
16. Tube calibration
17. Cutting
18. Finishing table

The prices of equipment depend a great deal on the manufacturer, how far the facility is up-to-date and/or automated. The prices below refer only to the equipment proper, without buildings and extra costs.

- Tube-welding line for the manufacture of small-diameter /12-50 mm/ tubes 800,000-1,000.000 dollars
- Narrow strip coil-coating line /maximum width 180 mm/ 500-600.000 dollars
- Profiling line for profiles of maximum 100 mm circular diameter 300,000-400,000 dollars
- Wide-strip coil-coating line /maximum width: 1,800 mm/ 6 - 9 million dollars

3.9 Processing of own shop scrap and of purchased scrap.

In the wake of rising energy prices, there is worldwide pressure for using available resources with utmost foresight and economy. As for aluminium, in line with this trend, nowadays growing attention is devoted to the recycling of own scrap arisings and of such obtained from outside sources.

According to European data, energy required in processing aluminium scrap is only 5% of the total energy involved in the integrated process of producing primary aluminium starting from bauxite.

Indeed, these not energy-intensive scrap-recycling technologies call for relatively small amounts of capital investment, only a fraction of what is required per ton of output in case of erecting an aluminium smelter.

Depending on local conditions prevailing on site and market demand as to quantity of and quality of remelted ingots, the annual capacities of such scrap-remelting facilities may vary from 1,000 tons to 50,000 tons. If not too high standards are called for, remelted ingots may be used with advantage by aluminium foundries producing simple castings. Modern major plants, however, are carefully selecting and grading such scrap so that they may be able to remelt them to secondary ingots to be used in the manufacture of semi-fabricated products. A case in point are throwaway drink-cans in America, in the manufacture of which more than 50% of the material used is collected scrap.

The price gap between purchased scrap and remelted ingots is very high. Therefore remelting is one of the most profitable operations of the aluminium industry, where, however, the magnitude of turnover and its proceeds are governed by a combination of local circumstanes /see also sub-chapter 3.33/, actual market demand, and funds available for organizing the collection and classification of scrap in an effective manner.

The economic feasibility of scrap processing and of selling remelted secondary ingots profitably is hinging on the following two important points:

- Careful and correct collection of scrap. /From aluminium scrap polluted with other substances or from a mixed bag of aluminium alloy scrap, impurities may not be effectively removed. In such cases, however up-to-date a remelting facility may be, it will produce only a metal of uncertain composition and inferior value/.
- Application of a suitable technology of melting to prevent the oxidation of the metal. /The necessity of this is evident from Fig.12, referring to the magnitude of melting losses occurring on employing conventional and advanced processes of remelting/.

In developed countries the volume of scrap arisings is 25-35% of the total amount of aluminium processed or used. This figure includes both shop scrap arisings and the collection of so-called "amortization" scrap.

Further details as to these two types of scrap are to be found in Table 11.

3.91 Technology of scrap remelting.

Recycling and processing of scrap is done in four subsequent stages, viz.

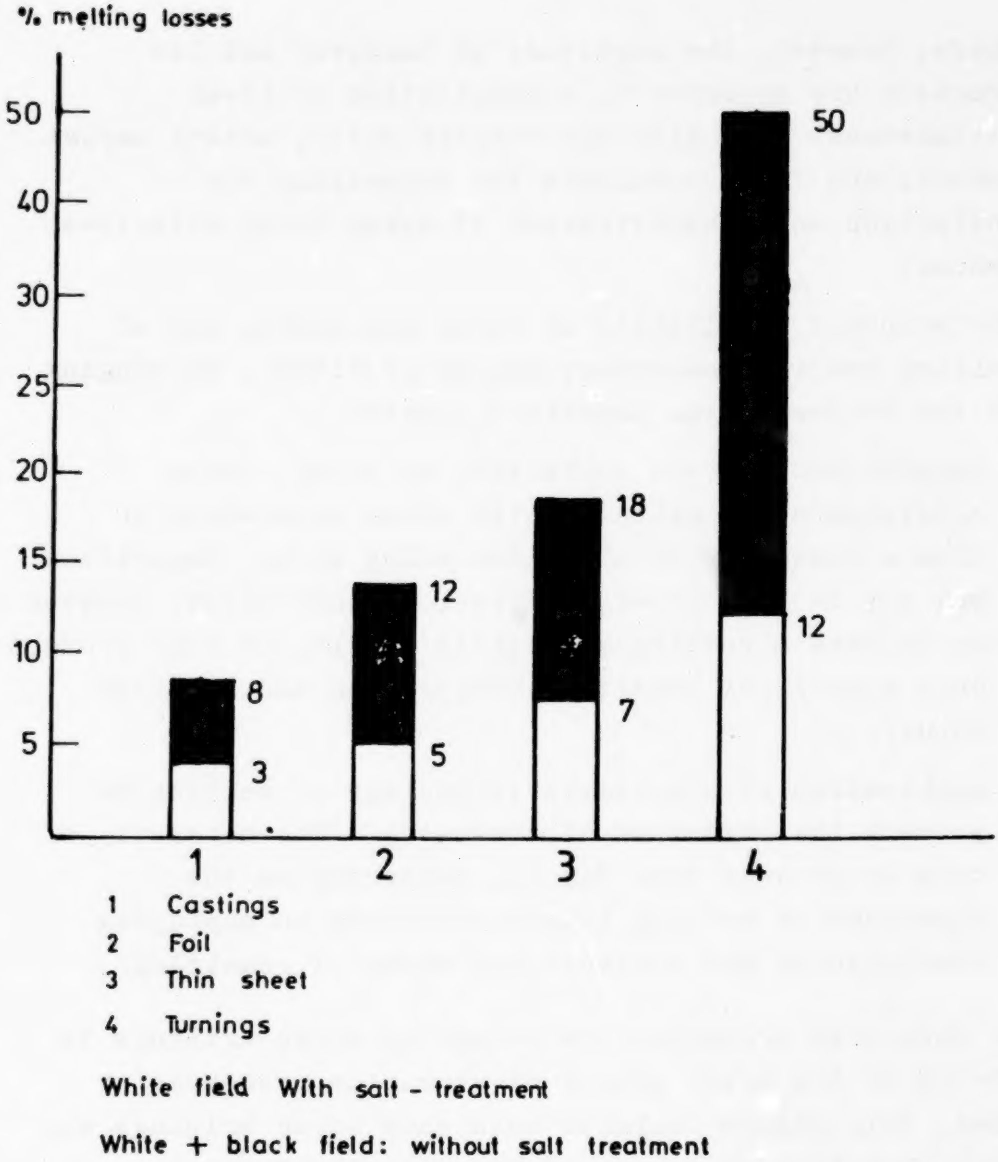


Fig. 12. Burning losses of different light metal scrap charges with or without salt treatment [25]

Table 11.

Main types of scrap - Types of alloys - Typical impurities

Type of scrap	Type of alloy	Typical impurities
SHOP SCRAP ARISINGS		
Sheet cuttings and edges	Wa	Plain and stainless steel
Extrusion ends	Wa	Lubricants
Packaging rests and reject	Wa	Paints and lacquer - paper - plastics
Turnings and chips	Wa+Ca	Steel -brass-lubricants-water-sand
Casting reject and deadheads		Steel and brass linings
Residues	Ca+Ma	Sand and fluxes
AMORTIZATION SCRAP		
From transport vehicle motor parts, pistons, sundry castings	Ca	Steel- brass- zinc and magnesium alloys -lacquers - oil- grease
Vehicle bodywork decorative components	Wa	Steel - brass-wire - lacquer - plastics
Building components	Wa	Steel - stainless steel - brass wire lacquers-rubber-plastics

Type of scrap	Type of alloy	Typical impurities
Cables and electrical equipment	Na+Wa	Steel wire- steel and brass screws-rubber-lacquers
Kitchen equipment, cooking utensils	Na+Wa	Iron- brass- bakelite- teflon
Selected packaging items /drink cans, bottle closures, collapsible tubes, foils/	Wa+Na	Lacquers and paints -paper-plastics-other organic substances
Printed sheets, scraps of electrical household appliances, office machinery, chemical and food-processing machinery	Wa+Ca+Ma	Miscellaneous as above

Na = Non-alloyed aluminium
Wa = Wrought alloy
Ca = Casting alloy
Ma = Mixed alloy

- Collection, storage and sorting
- Preliminary operations
- Melting, alloying and melt-treatment,
- Casting.

Effective collection of scrap is basically a matter of sound organization. In recent years, developed countries have made significant headway in this respect. At sites where major volumes of scrap are arising, or often also elsewhere, a fleet or baling presses and mobile collecting trucks etc. are facilitating the handling and dispatching of scrap. Special care is taken to keep scrap of discarded drink-cans apart. What is really important, is not to mix different types of scrap where they are arising or being collected. Therefore it is necessary to store aluminium scrap quite apart from other metals, and in doing so, even to keep different types of alloys in separate batches. With scrap collected from the population or with a seemingly worthless one, this in an almost unsurmountable job. Therefore before using such scrap, it has to be subjected to careful manipulations. Effective storage of scrap calls for plenty of space. An estimate of the latter is given below:

Type of scrap	Area required for storing 1 ton scrap up to 2-metre height /m^2/
Sheet cuttings	2.0
Castings and holloware	2.5
Lumps	2.5
Thin sheets, chippings	5.0
Foil	10.0

To produce alloys of good quality from scrap, special treatment before remelting is of great importance.

Whilst earlier most of the operator's attention was focused to the process of remelting proper, nowodays growing emphasis is given to separating the scrap from all foreign substances, to grade it properly, and to prepare a suitable composition of the charge for the process of remelting.

Preparing such charges in semi-fabricating plants from their own scrap is a relatively easy task. All basic equipment needed for this are shears and baling presses. Turnings and chippings are usually soiled with oil and liquid emulsions; their handling is therefore more difficult. First they have to be finely ground; following this oil and liquid stains have to be evaporated and all traces of iron removed. The resultant ground substance is thereupon compressed to 0.5-35 kilogramme blocks of 65-80% volumetric density. With amortization scrap the situation is different. It has to undergo mechanical, cryogenic, flotation and metallurgical treatment. The most widespread equipment used in mechanical treatment is the so-called "shredder", producing 3-25 centimetre size crushed mixed lumps of 0.9 ton/m^3 volume-weight. A dust-precipitator and de-ironer is directly attached to the mill. The output of larger units is about 20 tons/hour, and that of the smaller ones 1-2 tons/hour. It is expedient to have the scrap cut by means of special shears before shredding.

Manual sorting of crushed lumps of scrap is more and more giving way to a method based on the different density of substances. When scrap is added to a mixture of ferro-silicon and water, scrap is precipitating with the aid of hydrocyclones. Thus plastics, rubber, heavy metals such as Cu, Zn and others, as well as Mg and other impurities may be disposed of within a 1.8-3.3 gram/cm^3 density range. The installation of this high-duty line, however, is very costly. Where sufficient funds are not available, conventional methods of sorting have to be resorted to, based on the understanding that different metals have different melting points. A case in point is the liquation process, where from the sloping bottom of the melting chamber of a two-chamber furnace aluminium is flowing down into a collector, with iron and copper remaining in the furnace. This widespread method has one snag: the molten metal is inpure.

To treat recycled drink and non-drink cans several new technologies have been devised.

As for household rubbish, its very low /about 0.5-1%/ aluminium content is only worth while to be reclaimed in combination with a method of winning energy.

For remelting scrap and treating the molten metal, earlier gas- and oil-fired rotary drum or hearth reverbatory furnaces were used. Depending on the type of scrap, nowadays a growing variety of other two-chamber furnaces are employed, fitted with a feeding shaft, melting bridge or a charging pocket. Their two chambers are sited either horizontally or vertically one upon the other /see also Fig.7 in sub-chapter 3.33/.

The types of furnaces used in small or medium-capacity scrap remelting plants are to be found in Table 12. For remelting turnings and dross salt-bath rotary drum furnaces or nitrogen-chlorine converters are the most suitable. Another alternative is the remelting of turnings in induction crucible furnaces.

Table 12.

Aluminium scrap melting furnaces, compared

Type of furnace	Capacity ton	Melting output ton/hour	Energy consumption per ton of aluminium	Use of salts %	Burning losses %	Soundness of furnace walls Years	Length of annual repairs Weeks
Shaft furnace /Hearth reverbatory furnace/	2... 5	0.4...1.2	1200 kcal	2... 6	15 - 20	8...10	3...6
Hearth reverbatory furnace	3...10	0.5...1	900...1200 kcal	2... 5	6...10	1... 3	1...3
Hearth reverbatory furnace with feeding shaft	10...25	0.3...1	1000 kcal	6...10	3... 8	1... 3	1...3
Converter furnace	1...5	0.5...1.5	800...900 kcal	10...20	2... 8	1... 3	2...4
Drum furnace Rotary furnace	0.5...5	0.5...1.5	800...900 kcal	15...30	4...10	2... 3	1...2
Channel-type induction-heated furnace	0.5...6	0.3...1	520 KWh	0...3	2... 6	0.75...1.5	1...2
Crucible induction-heated furnace	0.5...6	0.3...1.1	550 kWh	0...3	2... 6	0.5...1.5	1...2

In order to purify the melt and to reduce burning losses, a salt mixture /NaCl + KCl + Na_3AlF_6 + NaF + + CaF_2/ is added, its quantity ranging from 0.5% to 40% of the charge. As for scrap of magnesium content, $MgCl_2$, too, has to be added. The favourable effect of such a salt mixture on burning losses is shown in Fig.12 (25).

Fluxes are generally suitable also for purifying the metal. Their use results in a dross of loose structure with only a small amount of metal inclusions.

Melts from secondary metal usually contain more oxides and gases than those from primary metal or pure shop-scrap. This is why nitrogen-chloride converters on one hand, and up-to-date semi-continuous and continuous purification processes as outlined in sub-chapter 3.31 on the other hand, are being widely used.

Alloying elements are being added either pure or in form of master alloys /see also sub-chapter 3.31/. In case of alloyed aluminium used in the manufacture of castings, also grain-refiners are being added. The Na content of AlSi alloys modified and improved before casting by treatment with P or Sr has to be reduced by careful treatment to a minimum. In processing scrap, a sizeable volume of dross is arising, amounting to some 5-8% of the molten metal weight. Such hot dross is containing 20-60% aluminium, of which about one-fifth may be recycled by direct salt-treatment or stiring in the hot state. Cold dross is thereafter still containing a large amount of aluminium. After crushing the cold dross, aluminium may be separated in a dry state from other non-metallic impurities. The resultant metal granulate is thereupon recycled to the furnace; the remaining residual powder may be used for various purposes. Depending on capacity, a dross-processing line may cost anything from several thousand to several 100.000 dollars. Reclaiming aluminium from dross, however, will certainly render the process of scrap-remelting a more profitable proposition.

3.92 Establishment of scrap-processing facilities.

As mentioned earlier, the processing and remelting of scrap is a venture greatly influenced by local conditions prevailing or site. In view of this, it is believed that such facilities with different capacity and standard of modernity will keep on to be viably operating side by side for a great many years to come.

Generally speaking, the installation of such facilities - especially such of smaller capacities - is not too capital-intensive. In fact, it is one of the least costly and under circumstances the most cost-effective ventures of an aluminium industry.

Fig. 13 is the layout-scheme of such a simple but efficiently operating small remelting plant processing scrap of the following annual composition:

Sheet and extrusion scrap	400-500 tons
Casting scrap	200-300 tons
Foil and thin-strip scrap	150-250 tons
Turnings and chippings	50-100 tons
Total input	800-1,150 tons.

After preliminary treatment, the charges are molten in simple rotary furnaces applying salts. Prior to casting, the melts are transferred to a gas-fired or electric resistance-heated holding furnace. Depending on local conditions, investment costs without building are in the order of one million dollars.

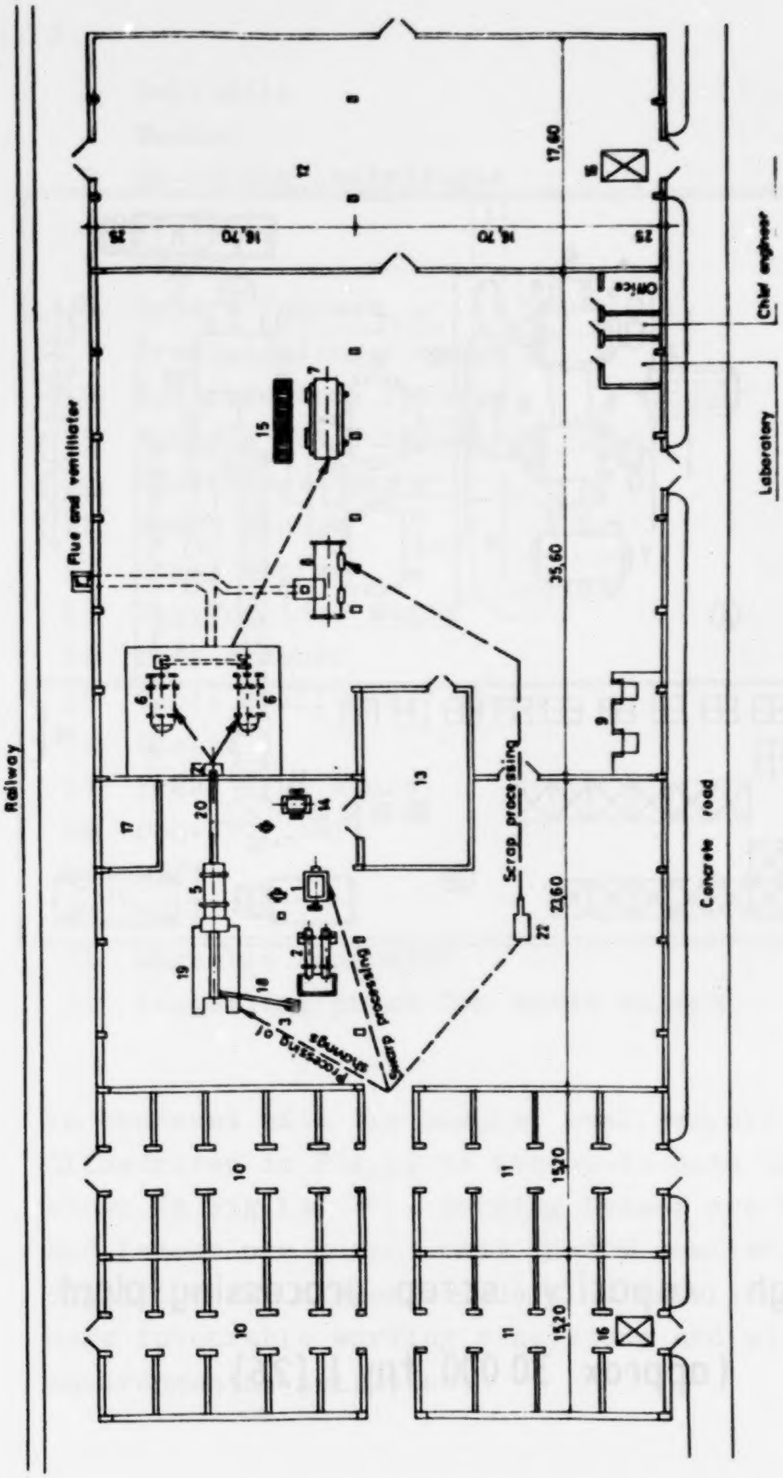


Fig. 13. Small capacity scrap processing plant (approx. 1000 tpy)

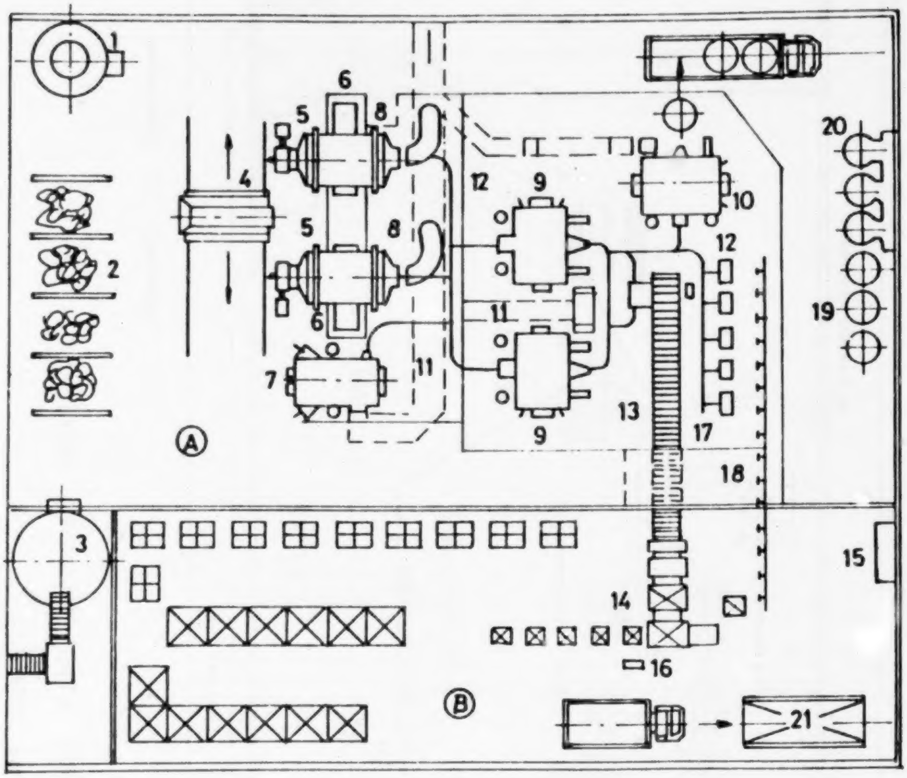


Fig. 14 High capacity scrap processing plant (approx 30 000 tpy) [26]

Fig.13

1 Ball-Mill
2 Washer
3 De-oiling centrifugue
4 Crusher
5 Dryer
6 Rotary furnace
7 Precipitating furnace
8 Reverberatory furnace
9 Tilting pot furnace 600 kg
10 Shavings stacks
11 Swarf stacks
12 Ingot store
13 Flux residue store
14 Flux crusher
15 Cont. chill-mould chain
16 Scales
17 Fresh flux store
18 Conveyor belt
19 Lift
20 Lift
21 Magnetic separator
22 Faggotting press for sheet scraps

In contrast with the simple, small-capacity plant illustrated in Fig.13 is its up-to-date counterpart shown in Fig.14 (26). Burning losses are 20-30% lower and labour per output unit 50-60% smaller, producing a significantly higher standard of remelted ingots under more favourable working conditions and with smaller environmental pollution.

Fig.14

A Casting Shop
B Ingot Storage
1 Salt /Flux/ Hoppers
2 Storage Partitions
3 Turnings Hopper
4 Feeding Equipment
5 Melting Rotary Furnaces
6 Slag Container
7 Melting Furnace /for materials having inclusions and of high iron content/
8 Fume Exhaustors
9 Tilting Converter
10 Holding Furnace
11 Flue Ducts
12 Troughs for Melt
13 Ingot Casting Unit
14 Ingot Stacking Unit
15 Switchboard for item 14
16 Control Panel for item 14
17 Casting Stations
18 Conveyor for Previous items
19 Crucibles to Transport Molten Metal
20 Crucible Preheaters
21 Weigh-Bridge

The minimum capacity of such an independent and modern facility is 15,000-30,000 tons per year. Its specific investment costs including building are in the order of 500,000 dollars per 1,000-ton annual capacity.

Within these two extreme cases, of course, various alternative projects may be implemented after taking local conditions /supply of scrap, availability of funds, infrastructure, local background of industry, standard and competence of workforce, etc./ into account.

3.93 Light metal foundries.

Principal users of remelted ingots are light metal foundries operating with technologies of sand-, die-, and different other variants of casting.

The simplest castingsare manufactured by foundries having only sand- and manual die-casting equipment. The smallest annual capacity of such foundries is 300-500 tons. Often they are located next to a small-capacity scrap-remelting plant.

By contrast, up-to-date large-capacity scrap-remelting plants are regularly supplying great volumes of remelted ingots to foundries that are turning out several thousands of more complex castings annually by high-duty pressure die casting machines of advanced design.

Sometimes molten metal is transported from scrap-processing plants by special vehicles in heat-insulated 2-3 ton crucibles over several 10 kilometres of distances to the foundries. By this, savings in investment and operation costs of the furnace, as well as a reduction of burning losses and economies in labour and energy may be arrived at. A case in point is the transport of molten metal by Affimet of Dammarin les Lys in France over a distance of 45 kilometres to the foundry of Citroen located in one of the Paris suburbs. High-duty pressure die-casting machines and their dies, however, are not only very expensive but also calling for great skill in handling them. Therefore the installation of such equipment may only be recommended in regions where sufficient engineering experience is available.

3.10 General considerations as to establishment and operation of the facilities /energy, maintainance, workforce, laboratories, etc./.

An important prerequisite of establishing an aluminium semi-fabricating plant is the availability of a complete infrastructure covering

- energy supply
- water supply
- a sewage disposal system and/or equipment for treating or destroying sewage
- a suitable road network
- the availability of auxiliary utilities and services essential in operating the facility
- housing, including such providing health and medical services and catering for the cultural and religious needs of the workforce, together with schools and an adequate network of shops, etc.

Fuller details of these may be found in another UNIDO study listed in the References (21).

Energy supply is essential for the direct operation of all technological equipment and auxiliary services /maintainence, transport, etc./. Unless served by a sufficiently large electric power grid, no facility may go on operating with safety. It is also useful to have a national gas- or oil-pipeline nearby.

Water supply is another priority in operating a semi-fabricating plant effectively; it is of paramount importance in the processes of casting and anodization. Water is seldom available in such volumes that its single utilization would be economical. Therefore an effective system has to be devised for recycling cooling water used in the course of operations. Sewage water has to be clarified in line with instructions by the local authorities.

Within the plant site, a network of roads has to be laid out so as to permit materials handling and transport by special vehicles and conventional trucks.

Among the auxiliary shops the maintainance shop is by far the most important. It is called upon to supervise the continuous operation of all technological equipment, to carry out maintainance work on them and to prevent their defective operation or breakdown. This shop is also manufacturing part of the components used in the plant. Capacity and equipment of the maintainance shop are also greatly influenced by factors, such as whether or not firms exist in the vicinity specialized in the manufacture and repair of mechanical and electrical engineering equipment, and if so, whether they have free capacities and are willing to work for the semi-manufacturing plant. Maintainance shops are furnished with the usual equipment /tool-machinery, heat-treating ovens, welding equipment, devices used for electrical repairs, etc./. Next to the man in charge, most of its staff have to be skilled workers as well as mechanics versed in machine and electrical repair.

Among other important auxiliary services are different storerooms /to keep and handle stocks of raw material, intermediate and finished products/, and the packaging shop. Packaging may either be mechanized or manual.

As to housing, its size and standard may vary with local conditions; notably, whether there is idle manpower in the neighbourhood, how far is the nearest village or town, etc. It should be remembered that it is of paramount importance for the plant to have a permanent and experienced workforce on whose services it may always rely.

If all infrastructure is not available right at the doorstep of the plant, it is up to the investor or the State to provide for what may be missing. Of course, the smaller a plant, the more difficult it is for it to defray such extra costs. In selecting a suitable location for a project, the problem of infrastructure, existing or one to be provided for, is always a crucial point. Another important consideration is the plant's distance to the end-using industries; transport costs may greatly influence the viability of a project.

The actual experience of individual workers in the operating divisions and auxiliary shops may be highly varied. Anyway, with each equipment or group of equipment there must be one or more competent persons in charge. The backbone of every plant are foremen and technicians who have to be fully competent or trained beforehand.

In the intermediate stages and at the end of the production cycle, quality control is an important task to be performed by suitably qualified teams of engineering staff.

Laboratories are in all semi-fabricating plants more or less similar. The quality of feedstuff /slab, billet, semi-continuous cast strip or coil/ is in most cases right at the outset determining the standard of the end-product. A good semi-fabricated item may not be manufactured from a poor material. The composition of material has to be first tested before starting semi-continuous or continuous casting, and finally at the end of the production cycle upon grading the product. Chemical analysis prior to casting has to be fast, therefore in modern plants this task is performed by multi-channel automatic spectrometers. Depending on the composition of the alloy and the properties of the product sought for, the metallographic structure of the feedstuff, too, has to be tested with various frequency. For this purpose test pieces are cut, chemically steeped and light-microscopically examined.

To determine the usual mechanical properties of semi-fabricated products, one or more tensile test machines are used; test pieces for this purpose are prepared in a separate small workshop. Should there be any specific demands as to the behaviour of a given product, the use of other testing equipment, too, may be necessary /e.g. in testing the susceptibility to deep-drawing of a sheet, a cup-drawing equipment, in measuring the "r" index of anisotropy a special instrument, or to test the susceptibility to anodization of a product, a small laboratory testing-instrument/. In rolling mills it is indispensable and in other semi-fabricating plants desirable to have also a simply equipped laboratory to test lubricants /oils and emulsions/.

When envisaging the implementation of a new project or the expansion of available capacities, it is always advisable to consult first of all one of the major aluminium advisory bodies, some of them listed below. They are familiar with all aspects of the aluminium industry and are usually prepared to answer first inquiries free of charge. Their names and addresses are as follows:

- Aluminium Zentrale /Aluminium Centre of the Federal Republic of Germany / Kőnigsallee 30, D-4000 Düsseldorf
- Information Service of the Central Technical Division of Alusuisse /Switzerland/, Feldeggstrasse 4, CH-8034 Zurich
- Centre Technique d'Aluminium /Technical Centre of Aluminium, France/, 87 Boulevard de Grenelle, F-75015 Paris
- Japan Light Metal Association, Nihonbashi Asahiseimei Bldg., 2 Nihonbashi Tori 2-Chame Chuo Ku, Tokyo 103
- Aluterv-FKI /Hungalu Engineering and Development Centre, Hungary/ Pozsonyi u. 56, Budapest

After decision makers have concretely made up their minds as to what type and size of a project to choose, the next step is looking for suitable technologies. Some technologies are furnished or sold for own equipment by the equipment-makers themselves; however, it seems more advisable to contact for know-how a semi-fabricator turning out the same or similar selection of items as envisaged to be manufactured by the future investor.

The following large international world companies may be prepared to sell various technologies and know-how, excluding such as designed for use by the armament industries:

- ALCAN Aluminium Ltd., Montreal, Canada
- ALCOA Aluminium Company of America, Pittsburgh, Pa. U.S.A.
- Compagnie Péchiney, Paris, France
- Kaiser Aluminium and Chemical Corporation, Oakland, California, U.S.A.

- Reynolds Metals Company, Richmond, Virginia, U.S.A.
- Alusuisse /Schweizerische Aluminium A.G./, Zurich, Switzerland

As for medium-size integrated operators:

- HUNGALU Aluminium Corporation, Budapest, Pozsonyi u. 56. H-1387, P.O.B. 30. /Hungary/
- Vereinigte Metallwerke Ranshofen-Berndorf, A-5282 Braunau/Ranshofen, Austria
- Vereinigte Aluminiumwerke A.G.D-5300 Bonn P.O.B. 2468 / FRG/
- EFIM. M.CS. Alluminio Italia I-00144 Roma Piazza G.Marconi 25 /Italy/

Some renown equipment manufacturers are as follows

- Melting and casting furnaces

  Ebner-Industrieofenbau. A-4021 Linz, P.O.B. 345. /Austria/

  Otto Junker GmbH. Lammersdorf D-5107 Simmerath, P.O.B. 1180 /FRG /

  Elhaus Industrianlagen GmbH. D-7703 Rielasinben l. Rudolf Diesel Str. 1-3 / FRG/

  Russ- Elektroofen Prod. GmbH. D-5000 Köln, P.O.B. 51 / FRG /

  KGYV-Metallurgical Engineering Co. H-1553 Budapest, P.O.B. 23. /Hungary/

  Industrieofenbau Fulmina Pfeil GmbH. Maaßstrasse 30, 6900 Heidelberg 1, P.O.B. 102227 /FRG /

  Wagstaff Engineering Inc. N. 3910 Flora Rd., Spokane, WA 99216 /U.S.A./

- Continuous casting equipment

  ALUSUISSE Caster A.G. CH-8034 Zürich, Feldeggstr.4. / Switzerland /

  Gautschi Electro-Fours S.A. CH-8274 Trägerwilen, P.O.B. 20. / Switzerland /

  SECIM Group Creusot-Loire. F-92402, Courbevoie 107 Bd de la Mission-Marchand /France/

  Continuous-Properzi Spa. I-20122 MILANO, Via Cosimo del Fante 10 /Italy/

  LOMA MACHINE A Hill ACME Co. 56 Harrison St., New Rochelle, NY 10801 /U.S.A./

  Hunter Engineering Co Inc. 1455 Columbia Avenue, Riverside, California /U.S.A./

- Casting facilities incl. scrap-recycling

  Gautschi Elektro-Fours S.A. CH-8274 Trägerwilen, P.O.B. 20 /Switzerland /

  LOMA MACHINE A Hill ACME Co. 56 Harrison Street, New Rochelle, NY 10801 /U.S.A./

  Union Carbide Industriegase GmbH. D-6000 Frankfurt am Main 71, Rhonestrasse 4 /FRG/

  Lindemann KG-GmbH. D-4000 Düsseldorf Erkratherstr. 401. /FRG./

  Brown Boveri Corp., Electroheat Div., North Brunswick, N.J. 08902 /U.S.A./

- Scrap Recycling

  Dr. Schmitz + Apel Industrieofenbau GmbH. D-5600 Wuppertal 22, Clausewitzstrasse 82-84 /FRG/

Pontzen Engineering GmbH. D-4400 Münster, Hammerstr.95
/FRG /

- Rolling mill

Schloemann-Siemag A.G. D-4000 Düsseldorf, P.O.B. 7240
/FRG /

Achenbach Buschlütten GmbH. D-5910 Kreutztal /FRG /

Walzmaschinenfabrik August Schmitz GmbH. D-4000
Düsseldorf 30, Oberrather Str. 4 / /

Scal Engineering. F-38700 La Tronche, 14-1 Boul de la
Chantourne /France/

Davy-Ashmore Ont. Ltd. Darnall Works Sheffield 9 / England

Sumitomo Heavy-Industries Ltd. 1 Kanda Mitoshiro-CHO,
Chiyoda-KU, Tokyo 101. /Japan/

- Extrusion press

Schloemann-Siemag A.G. D-4000 Düsseldorf, P.O.B. 7240
/FRG /

Sutton Engineering Co. PA-15219 Pittsburgh, 4 Station
Square /USA/

Davy-Ashmore Ont. Ltd. Darnall Works. Sheffield 9 / England

Mannesmann Demay Hüttentechnik Geschäftsgruppe MEER
Hydraulik. D-4100 Duisburg 1. Wolfgang-Reiter Platz /FRG

Fielding and Platt Ltd. Gloucester, GL15RF, P.O.B. 10
/ England /

SMS Hasenclever Maschinenfabrik GmbH. Witzelstrasse 55.
D-4000 Düsseldorf 1 / FRG /

KOBE STEEL, Ltd. Machinery Division. Tekko Bldg. 8-2,
Marunouchi 1-chome, Tokyo 100, /Japan/

SECIM Gr. Creusot-Loire Morane-Somma. F-92402 Courbevoie, 107 bd de la Mission Marchand /France/

EFIM Breda Fucine. 20100-Milano P.O.B. 10429 /Italy/

ASEA Area Manager Export Dep. S-721 83 Västerås / Sweden /

- Heat-treatment

Otto Junker GmbH. Lammersdorf D-5107 Simmerath, P.O.B. 1180 / FRG/

Bloom Engineering /Europa/ GmbH. D-4000 Düsseldorf, Burgplatz 21-22 /FRG /

BIRLEC Ltd. Westgate, Aldridge, Staffordshire / England /

HEURTEY S.A. PARIS XVII^{e} 32, Rue Cinersant /France/

TÜKI /Tüzeléstechnikai Kutató Intézet/ H-3515 Miskolc /Hungary/

Industrieofenbau Fulmina Pfeil GmbH. /Maass-strasse 30, 6900 Heidelberg 1, P.O.B. 102227 /FRG/

- Finishing equipment of rolled or of extruded products

Karl Fr.Ungerer GmbH. Maschinenfabnik D-7530 Pforzheim, P.O.B. 1940 /FRG /

F.W.Elhaus K.G. D-5600 Wuppertal 1, Hofkamps 140 /FGR/

WEAN - DAMIRON /Filiale de Wean United Inc./ F-75116 PARIS 10, Place des Etats-Unis /France/

WELLMAN Int.Eng.Ltd. LONDON S.W.1. Wilton Road Parnell House / England /

Stamco Bath House, Bath Street, Walsall, WS13DB West Midlands / England /

Oliver Machinery Co. 1025 Clancy Avenue, N.E. Grand Rapids, Michigan 49503 /U.S.A./

- Machines for Conform process

  Babcock Wire Equipment Ltd. Beaver Industrial Estate,
  Ashford, Kent TN23 1SH, /England/

  Holton Machinery Ltd. Holton Heath Trading Park, Poole,
  Dorset BH 166LF / England /

- Extrusion die manufacture

  Bridgeport Machines Division of Textron Ltd. Forest
  Road, Leicester LE5DFJ, P.O.B. 22, /England /

- Coil-coating

  Hunter Engineering Co Inc. 1455 Columbia Avenue,
  Riverside, California /U.S.A./

- Forging presses

  SMS Hasenclever Maschinenfabrik Gmb.H Witzelstrasse 55,
  D-4000 Düsseldorf 1 / FRG /

- Anodizing

  Blasberg Oberflächentechnik GmbH. D-5650 Solingen 13,
  P.O.B. 130251 /FRG /

In recent times the product-mix is fastly expanding; this is coupled with substantial changes in product standards and improvements in technologies and manufacturing equipment. There is now keen competition on these markets, and this state of affairs is expected to perpetuate. While a single instance of purchasing know-how is of great help in launching a new project or modernizing old facilities, it does not always represent latest advances in technology. In the long run, purchase of know-how alone may no longer suffice; hence the operator will have to train or engage teams of technical development specialists to follow latest achievements of modern technology. Such teams will have to be sufficiently competent not only to consider the advisability of purchasing further know-how, but also to be familiar with how to adapt and use it when introduced. Early organization of such a technical development team as well as the purchase of basic laboratory equipment are in the interest of the investor, for it may take at least 3-5 years until sufficient experience is accumuleted to run a plant effectively. As far as semi-fabricated products for the armament and aircraft industries are concerned, here the situation is more difficult.

To sum up, before a project may take concrete shape, a multiplicity of problems in the field of know-how, technology and engineering has to be resolved. Evidently, it is advisable to entrust such complex matters to a renown firm of specialists and to buy know-how from a semi-fabricator of great experience and good reputation.

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4. DEMANDS AS TO THE STANDARD OF PRODUCTS WITH SPECIAL REGARD TO THE STATE OF TECHNOLOGICAL ADVANCE AND MARKETING POSITION OF THE END-USERS

Almost from the moment of their commissioning, semi-manufacturing plants in developing countries may be called upon to export certain volumes of their output. Obviously, the economically feasible minimum capacities in such areas are far too big to be absorbed by the domestic market alone in view of the absence of a sufficiently developed local infrastructure and industry. In trying to penetrate the export markets, however, the plant is immediately faced with heavy competition from operators in developed countries both in quality and price. To some extent this is also true for the domestic market; the local consumer has alwas the option of buying from a foreign firm in a developed country abroad, if the local manufacturer is not competitive enough. Hence quality and production costs are key issues equally affecting the business of a producer, irrespective whether he is operating in a developing or developed country. Decision makers in developing countries have therefore carefully to watch and draw necessary conclusions from market and technical development trends, for these are significant in launching a new project or selecting a certain type of technology in a developing country. Of course, when selecting such technology ultra-modern and strikingly advanced methods do not necessarily have to be chosen, but fair, commercially accepted technology and equipment meeting general standards may be applied. What may in this respect be a real line of demarcation between developing and developed countries is the difference in their end-use pattern /see sub-chapter 3.2 and references (1), (2) and (3), which has always to be taken into consideration.

Throughout the world the quality of semi-fabricated products is governed by standard specifications. There are four types of these:

a. National general standards

b. International standards, e.g. ISO or COMECON

c. National standards concerning a limited group of special products /e.g. DIN 1784 about tolerances of thin-strips, or DIN 17 615 about precision profiles from alloy 6063/, and

d. Separate stipulations agreed upon by customers and semi-manufacturers.

International standard specifications /b/ are a combination of various properties and parameters set forth in national standards; their rulings, however, are less stringent than those of the national ones, and are therefore only seldom applied in concrete orders.

Products of commercial quality are usually ordered according to national standards /a/. Influenced by a changing pattern of increasingly exacting market demand, a good many of them feature parameters varying from country to country /e.g. thickness, dimensions, shape/. Also their general layout and the manner in which they are compiled may differ from case to case. Anyway, products turned out by the semi-manufacturer have to comply with the standard specifications under which they have been ordered. To be on the safe side, however, semi-fabricating plants apply as a rule special shop standards with more severe specifications than those demanded by national standards.

As for national standards concerning some special products /c/, these are basically target standards dealing with a limited range of items.

Separate stipulations between customer and manufacturer with or without additional charge to the former /d/, call for extra-high quality, and are the outcome of keen competition. Evidently, the end-user is anxious to manufacture better and more attractive items than his competitor; in view of this, he is willing to place his order only to a firm, whose quotation in terms of price and quality is especially favourable for him. In such cases properties and parameters are particularly strict, frequently approximating the uppermost bounds of what is technically possible at all.

In recent years several attempts have been made to grade semi-fabricated products according to their utility as seen and valued by the markets. Here is one example of such a classification:

- Expensive items with plenty of know-how embodied in them to be used by the most demanding type of customers e.g. by the aircraft or computer-electronics industry
- Products of higher than average prices, having special properties for specific end-uses e.g. sheets and discs suitable for anodization, deep-drawing or teflon-coating
- Products of commercial quality, generally sold by metal dealers or stockists; these are the most price-sensitive ones; their list prices are only 1.2-1.4 times that of primary ingots.

Another type of grading to be found in literature (4) refers to the extent of probable hazards the manufacturer may be faced with in turning out semi-fabricated products of varying properties by means of technologies involving different intensities of efforts. According to this so-called "risk" concept products may be

- small-risk /cladding-profiles, holloware discs, lacquered strips, corrugated sheets, etc.
- medium-risk /structural sections and sheets, electrical conductors, foils, thin-strips, etc./
- high-risk /free-cutting alloys, high-strength rods, motorcar components, aircraft plates and sheets, etc./

In the following, principal demands as to, and the most frequent defects occurring in, quality are dealt with at some length.

4.1 Rolled products.

The most frequent defects in rolled products may be summarized as follows:

- Mechanical and metallurgical defects. Streaking due to uneven concetrations of alloying constituents, course grains, blistering, inclusions, pores, micro-cracks, insufficient mechanical strength, earing, and deformation streaking occurring in the process of forming /Lueders lines/.
- Defects in dimensions. Defective length, width and thickness; swordness of edges, defects of right-angularity.
- Defects in shape. Waviness at the edges and in the centre, curving sheet corners, longitudinal and transverse bends, etc.
- Defects in surfaces. Roll imprints, fishbone patterns, oil burns, traces of levelling, quenching spots, scratches and blows.

- Coiling defects. Ovality, telescopicity, etc.
- Cutting defects. Burrs, detached edges, etc.

Also in case of rolled products, adherence to standard parameters may often not suffice in getting an order. Today the manufacturer is frequently expected not to exceed 50% of gauge tolerances demanded by the standards. Moreover, standards may not always cover all special wishes of the customer. Therefore in a good many cases the manufacturer is called upon by the customer to accept special stipulations. In qualifying such a product and identifying its properties, usually sample specimens /"etalons"/ are used. As a rule, extra stipulations are only agreed upon when it comes to ordering a product of higher grade class with special properties /e.g. anodizability, special reflective lustre, unusual dimensions, more stringent demands as to mechanical strength and smaller scattering of the latter, etc./.

In most cases, testing of quality at certain intermediate stages of production combined with final quality control on a statistical basis may suffice. In manufacturing some specific items, however, /e.g. semi-manufactures to be used by the aircraft industry/ the customer may insist on having each plate or sheet to be tested separately.

Sometimes the customer is not referring to a concrete standard specification in his inquiry, but merely pointing out what he wants the product for. In such a case the manufacturer has to recommend a product at his own responsibility.

It is advisable to keep records of specifications demanded by the customer, because it may happen that he wishes to order an item "such as had been received several years earlier".

4.2 Extruded and drawn products.

In discussing market expectations as to quality of extruded products, it is expedient to start dealing with sections made from alloy 6063; a new extrusion plant in a developing country is most likely to begin its operations by manufacturing a larger volume of items under this particular heading to customers in the area.

This group of extrusions includes both solid and hollow sections for a multiplicity of purposes. The major part of them are used for the manufacture of window frames and other non load-bearing building components, but also considerable volumes are taken up in the manufacture of transport vehicles and consumer durables /e.g. cases for personal computers, etc./.

Quality demands as to such extruded products are as follows:

- Attractive appearance throughout; in most cases anodized, more recently also painted surfaces; with this end in view, high-quality billets have to be extruded; their production has to be ensured by a suitable casting technology /see sub-chapter 3.321/. Moreover, extrusion dies of high quality will have to be used so as to produce perfect surfaces; special care in materials handling to prevent demage to surfaces.
- Thin-walled complex sections being used in window frame manufacture, strict tolerances as to dimensions and shape have to be observed. It should be remembered

that window frames have to be water-tight and well-insulated, and that on assembly the sections have to be fitted to one another by sliding or clicking. A case in point are tolerances of distance between the two open ends of a half-open /e.g. U-shaped/ profile as below:

In national standards	± 0.7-0.9 mm
According to DIN 17.615	± 0.4 mm
According to a window manufacturer in the Federal Republic of Germany	± 0.2 mm.

Observation of strict tolerances is ensured by applying high-precision dies, keeping to optimum manufacturing parameters, the use of a puller and by increased rigidity of the press.

- With these products great mechanical strength is not of paramount importance; what really matters is high productivity. Therefore within the alloy 6063 semi-manufacturers have developed 4-5 variations of specifications, wherein each alternative of mechanical strength may be linked with highest productivity and optimum quality of surface. In order to protect their surfaces, these products may not be solution heat-treated at furnaces but have to be quenched at the press.

The group of semi-fabricated products discussed next has a combination of properties different from the one above. They are medium-strength load-bearing structural sections for the transport vehicle and building industries, usually manufactured from alloys 6181, 6082 or 7020. These products have as a rule stronger walls and are of a less complex design than those dealt with in the previous paragraph. Also their tolerances in dimensions are less severe, except where they have to be joined by clicking. Demands as to surface quality, too are less exacting and are governed by the various national standards. What is really important, are mechanical properties, and when used in transport vehicle manufacture, especially the dynamic behaviour of the material, such as fatigue limit, the energy of dynamic crack propagation, toughness, etc. To produce a suitable material for such ends, oxide inclusions have to be eliminated /see sub-chapter 3.31 about treatment of the molten metal/, and manufacturing parameters have to be kept within narrow limits. Some of these products may still be quenched by water spraying or submersion at the press.

Particular attention has to be devoted to the manufacture of extrusions used in aircraft manufacture and/or repair. In this field heavily alloyed high-strength alloys /e.g. 2024, 7075/ have to be used. Products made thereof are highly susceptible to general and stress corrosion, and to assuming a coarse-grained, brittle structure. Their manufacture, therefore, calls for stringent technologies and quality control.

Obviously, the manufacture of such exacting products may only be taken up when the semi-fabricating plant has already acquired sufficient experience in turning out products of a less complex nature, but even then on the condition that such efforts are supported by very effective local research and technical development work.

As for drawn items, the tolerances of dimensions are very strict, especially if the end-user belongs to the electronics industry. Hence, drawing has to be applied whenever high accuracy in dimensions has to be complied with. In producing drawn items, demands on the preceding operation of extrusion, too, are very high. Only a material of good quality extruded with utmost care /e.g. in case of tubes eccentricity is an important consideration/ may be passed on to the drawbenches. Good dies and the application of lubricants is another prime necessity.

4.3 Electrical conductors.

In this field, properties called for are complex and very strict. A good conductor, notably, has to meet several, at first sight often seemingly contradictory demands. Thus, optimum conductivity has to be reconciled with maximum tensile strength, creep-resistance and plasticity /number of twists and plyings/. Owing to keen world market competition, even rulings by the most widely accepted standard specifications may only be regarded as a minimum demand. Before awarding a tender, the candidate striving to get the order is expected to produce sufficient evidence as to how much the properties guaranteed by him are superior to parameters set forth in various standards /e.g. those of ASTM of the USA, VDE of the Federal Republic of Germany or those of the international ISO/.

Conductors are made from E 99.5% unalloyed aluminium or E AlMgSi alloy /see 3.6 sub-chapter/. A good conductor has to have superior properties after removal of all harmful micro-impurities /Ti, V, Mn, Cr, Na, etc./ by boron treatment and other methods of purification. In case of unalloyed aluminium, the Si-content has preferably to be reduced to below 0.1%.

The optimum Si-Fe ratio is 1:3.

Today the most widespread initial operation of producing conductors is continuous rod-wire casting of unalloyed and alloyed aluminium /see sub-chapter 3.61/. In producing a finished high-standard product /conductor wire or strandings thereof/ the quality of rod wire coils is of paramount importance. Next to a strictly controlled and balanced combination of conductivity, tensile strength and elongation, rod wire produced in coils of 1-3 tons has to have a uniform quality throughout. Thus e.g. in case of unalloyed material, scattering of tensile strength within the same coil may not exceed ± 5 N/mm^2, and that of resistivity has to be smaller than ± 0.1 Ohm mm^2/km; the surface of rod wire has to be perfect, without scratches and stains; no ovality of coils is permitted, and the wire has to be wound in a neat, orderly and tight manner. In most cases terms as to quality are stricter than those called for in the standards. Final quality of the conductor is tested either after its drawing to desired gauge or in the stranded state. Owing to the fact that the rod wire manufacturer and the works where the wire is drawn and stranded are frequently different firms, controversies as to quality may from time to time arise. It should be understood that the final quality of a conductor is also considerably influenced by the operation of drawing /excessive generation of heat in the wire/ and the manner in which alloyed wires are heat-treated. To obviate such controversies, the two manufacturers may agree to set aside and keep one coil each as a sample to be drawn to final gauge by a neutral operator whose findings would be binding.

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5. MARKETING OF ALUMINIUM PRODUCTS IN DEVELOPING COUNTRIES

The establishment of an aluminium industry in developing countries, whether in dentrally planned or market economies, is always a matter in which the governments take a keen interest. When envisaging such projects, the first step is to set up - with state-sponsorship or without - a body sufficiently familiar with all commercial and technological implications of the matter, capable of promoting the realization of such schemes, and to help later on the newly established industry to organize the marketing of its products. Even in this ongoing phase of technical development, it has to be the nucleus of a future marketing and technical advisory organization to render the venture a technologically effective and financially sound proposition. In going ahead with such projects, the services of foreign firms experienced in technical development, designing and engineering, combined with the purchase of know-how, the engaging of specialists and the concluding of joint venture arrangements, may greatly expedite preparatory work and reduce the time necessary for the concrete implementation of projects. Subsequently, operators of the aluminium semi-fabricating industry have to set up research, development and engineering facilities of their own. Experience obtained thus far has to be permanently upgraded by following in the shortest possible time latest developments in technology, and by exchanging information with other developing countries.

Such centralized or de-centralized marketing agencies are to be established in the wake of this, and have to cooperate closely with all local producers, industries, as well as technical development and advisory bodies, so as to ensure optimum efficiency of their sales efforts.

5.1 Economic benefits of specialized marketing organizations for semi-manufactures

Every country or firm operating an aluminium industry in developing countries has to develop a business strategy of its own, which has to be flexible enough to cope with market fluctuations. Even the installation of a new equipment may affect and alter such a business strategy. In defining it, the range of products to be put on the market is an important consideration. As a rule, only items of attractive design, good quality and mass-manufactured by modern equipment are suitable to be exported /for grading such quality see Chapter 4/. In exceptional cases, however, also items produced in conventional shops may be exported profitably /see sub-chapter 2.31/.

New products have to be marketed in the following three steps:

- Introduction of the product on the domestic market,
- Exports to regional markets, and
- Exports to world markets.

The situation is different when the plant is installed with the aid of foreign capital or know-how furnished by one of the major aluminium companies. Here there is a growing trend by these companies to accept large shipments of commercial-quality semi-manufactures in compensation for their capital investment. This practice, usually governed by long-term agreements, is vary advantageous to the semi-fabricating plant of a developing country; not only does it permit a better utilization of available capacities, but also to derive extra benefits in the pricing of products wherein operations of higher finish and more labour are involved. Related to aluminium ingot, such phase-differences in pricing are tabulated below:

Aluminium ingot	100%
Continuous-cast rod wire coils	115%
Continuous-cast strip coils	120-125%
Unalloyed and weakly alloyed strip coils of 1.5-0.7 mm thickness	130%
Thin strip of commercial quality	140%
Thin strip of special quality /minimum/	150%
Foil of commercial quality	180%
High-finish foil	210-250%
Low-alloyed extruded sections	180-220%
Low-alloyed extruded sections of anodized surface	220-250%

However, when operators find output to grow faster than actual demand, they have to realize that the shortfall is not always due to a poor sales policy, but is often caused by market speculation rather than by unbalanced demand and supply.

5.2 Few suggestions for the possible organisation of specialized marketing orgasisations.

In operating on the domestic and export markets effectively, it is necessary for the sales organization to keep close contacts with the various end-using industries and the agencies responsible for technical development. This applies equally to countries of centrally planned and market economies.

Another important task for the sales organization is to fix prices of products sold in varying volumes, and to adopt a certain pattern of pricing system. There are two alternatives of the latter:

- Buyer and seller agree - for a definite length of time, usually long-term - to carry out business on the basis of prices tied to the so-called official aluminium ingot market price. This is the usual pricing model practised by the international metal trade, based on co-operation and mutual understanding between the two parties.
- Under the second model, prices of semi-manufactures are determined by the market quotations of the Metal Exchange of London or COMEX of New York. In this case, semi-fabricated products become typical market commodities exposed to ups and downs of fast fluctuations, with small chances of contacts between buyer and seller.

Adopting an effective pricing system calls for a great deal of experience and foresight on the part of the trading organization. As to how such a trading organization may best operate in a developing country, several alternatives and combinations thereof exist:

- An independent semi-fabricator is running a combined sales and technical development division of its own. /This applies in the first place to enterprises operating under the model discussed in sub-chapter 2.33/.

- The semi-fabricating plant is directly or indirectly integrated into the framework of a national or major aluminium smelting company, in this event the manner in which marketing and sales are to be organized largely rests with the multinational, whose part or subsidiary the plant is. /This applies in the first place to semi-fabricators operating under the model discussed in sub-chapter 2.32/.

- The sale of aluminium semi-manufactures is a high priority of the government's domestic and foreign trade policy; in this event it is advisable to combine marketing and technical development into the frame of a single, centrally controlled organization.

- And finally, when several smaller finished product manufacturers are operating in the country mainly catering for the domestic market, it is expedient to persuade them to enter into voluntary partnership in a joint technical development and marketing agency /see sub-chapter 2.31/. How such organizations may work, is explained in more detail in a separate UNIDO study entitled "The Economic Use of Aluminium".

RECOMMENDATIONS

Prompted by economic and political considerations, as well as the necessity of better utilizing available energy and human resources, developing countries nowadays more and more seek new ways of expanding their share in world primary aluminium production. In the wake of growing aluminium demand, there is also an increasing pressure of having semi-fabricated facilities installed in their own regions. A further impetus to such trends is given by several recent developments which may be summed up as below:

- Smelting and semi-fabricating operations are geographically coming nearer to each other since the introduction of continuous-casting technologies;
- With growing specialization, a large variety and optimum combinations of new aluminium-processing technologies have emerged;
- Developing countries are becoming more and more actively engaged in world-market operations of semi-fabricated products, at a time when more stringent standards have to be complied with under conditions of a more difficult economic climate;
- The advances referred to above cannot be kept pace with, but by obtaining greater expertise by those freshly entering the field.

The aluminium semi-fabricating industry - especially in developing countries - is a typical field for the necessity of and opportunities for technology transfer.

In order to facilitate that developing countries acquire the necessary know-how to operate aluminium semi-fabricating industies on their own with an optimum of techno-economic efficiency and to proceed in decision-making with utmost foresight, the following recommendations may be made:

1. Publication and widespread circulation by UNIDO of studies like that entitled "Guidelines for Processing Aluminium Semi-Fabricated Products". It seems advisable to supply these studies to:
   - specialists and decision-makers in developing countries,
   - multi-national aluminium companies,
   - representatives of companies and institutes likely to be interested in the international exchange of experiences, and to
   - executives of firms manufacturing equipment for the semi-fabricating industry.

2. Organization of an international symposium or conference preferably under UNIDO sponsorship - where representatives of the above four grous may confer. Such an event would be instrumental in promoting the establishment of semi-fabricating industries in various developing countries, while safeguarding also the interests of all parties concerned. The organization of this event could be entrusted to an institution which - beyond great practical experience in the given field, based on everyday routine activities - is also fully familiar with latest technological advances in developed countries of both free and centrally planned market economies, as well as with conditions and experience of transferring such technologies. An institution, which could be eligible for this exercise may be, among others, the HUNGALU Engineering and Development Centre, ALUTERV-FKI, Pozsonyi ut 56, H-1133 Budapest, Hungary.

   The success of such a meeting would be greatly enhanced if interested equipment manufacturers, actively participating in the event, would be prepared to organize and finance on-site acquaintance by the participants with their equipment operating in plants at different locations within the geographical region where the conference would be convened.